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METEOROLOGY

USSR-CUBAN RESEARCH ON HURRICANES

Moscow PRAVDA in Russian 11 Mar 82 p 4

[Article by P. Bogomolov: "Curbing the Forces of Nature"]

[Text] The 20th anniversary of the national Academy of Sciences, established with the active cooperation of the USSR and other socialist countries, is now being celebrated extensively in Cuba. Today we will tell about one of the directions in cooperation of Soviet and Cuban scientists.

Our conversation with V. Teslenko, director of the Obninsk Institute of Experimental Meteorology, who heads the marine expedition of the State Committee on Hydrometeorology and Environmental Monitoring along the shores of Cuba, transpired aboard the "Akademik Korolev." Together with another ship of the Far Eastern Hydrometeorological Institute, the "Priboy," it sailed for about 50 days in the Caribbean Sea. In the course of the year there is an average of 8 to 10 hurricanes of different force here. These inflict serious losses on Cuba and the other countries of the region. A study of the mechanism of development and movement of hurricanes for the purpose of learning how to predict them, such is the complex task which Soviet and Cuban scientists undertook.

The onset of cooperation between the USSR and the Republic of Cuba in the field of tropical meteorology and investigation of hurricanes was marked by an intergovernmental agreement which was signed in 1977. A mixed working group was formed in accordance with this document. Among its tasks was the direction of a joint laboratory of tropical meteorology which was organized in Havana.

Another direction in cooperation was the creation of a center for hydrometeorological investigations in Camaguey Province. For this purpose our Cuban friends were supplied a "Meteorit" radar station and also other scientific equipment from the USSR. The young group of specialists in Camaguey did a good job in giving land support to the efforts of Soviet and Cuban seamen and scientists present on the ships. Because of such interaction the expedition became truly complex.

One of those who works aboard the "Akademik Korolev" is Alfredo Moreno, co-director of the joint laboratory in Havana. We go with him through the ship, which has become a sort of floating institute. An apparatus for atmospheric sounding is placed on the stern. Peaceful rockets fly from there to an altitude as great as 90 km. There, separating from the housing, the nosecone with the instruments begins its

descent by parachute, transmitting to the ship information with data on air temperature and humidity.

"This entire operation lasts 50 minutes, no more," explains A. Moreno, "but on the other hand the processing of the collected data formerly required two days. Now, however, it is a completely different matter. The 'accelerator' of this work was the ship's computation center, where we are now going..."

"The electronic computer set up in the ample cabin is of the type adopted in the member countries of the Socialist Economic Bloc -- the Unified Electronic Computer System Complex. Its capability for performing tens of thousands of operations per second makes it possible in one hour to process data whose integration earlier required many days."

"In order to explain why such a speed is necessary," continues A. Moreno, "I will mention the three principal factors predetermining the development of a hurricane. These are temperature, cloud cover and moisture. The relationship of these unstable components is constantly changing. If the computations are not successful the 'dynamics' of the experiment as a whole is lost. And each experiment is a new step toward an understanding of a mystery: why does one cloud cover field bring rain, whereas another causes a hurricane?"

The physicomathematical modeling of atmospheric processes, becoming possible due to electronic computers, raised the activity of the expedition to a qualitatively new level. The processing of operational information was supplemented by a parallel analysis of the archival data which was provided by the Cuban Institute of Meteorology.

Climbing to the bridge, we met ship's captain G. Surzhenko there.

"Usually seamen," he states, "strive to avoid hurricanes. We, however, conforming to the desires of the scientists, proceeded in the opposite way: dropping anchor in those regions of the Caribbean basin where the strongest winds are possible. The crew did its duties with full understanding."

"It so happened that the specific results of the expedition could already be checked a week after its completion. At that time the tropical hurricane 'Catrina' was roaring through the Cuban province Camaguey. But this natural calamity did not catch the people unawares. Relying on scientific data, the Cuban Institute of Meteorology foresaw an advancing low-pressure area. Operational data from the 'Meteorit' station again were of assistance. As a result, in the most dangerous regions it was possible to evacuate about 33 000 inhabitants in time. Civil defense activists and shepherds led more than 60 000 head of cattle from the zone of torrential downpours."

"Intensive work on analysis of the information jointly collected by Soviet and Cuban scientists is continuing. The Cuban and Soviet specialists of the joint hydrometeorological laboratory have also not failed to take note of additional materials which are of a secondary importance in the study of hurricanes. For example, this includes information on contamination of the atmosphere and waters. It would be an error to ignore such data, considering them to be 'auxiliary' or 'unnecessary'."

"The very mechanism of cooperation is also being improved. In particular, it was decided that in the future there would be other expeditions similar to that which has already been carried out. The sessions of the mixed working group are to be supplemented by annual symposia of Soviet and Cuban hydrometeorologists."

"It is difficult to overestimate the importance of the Soviet-Cuban cooperation in the field of investigation of tropical hurricanes," declared Wilfredo Torres Iribar, president of the Cuban Academy of Sciences. "The data collected by the difficult work of hydrometeorologists are related to a problem of vital importance for Cuba. It is now becoming possible to formulate a more reliable model of the development of hurricanes and this promises to be of great advantage to the national economy of the republic. The ability to predict abrupt changes in weather will make it possible to notify the population in advance concerning advancing weather disasters."

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WORK OF 'AKADEMIK KOROLEV' DESCRIBED

Moscow PRAVDA in Russian 16 Jan 82 p 6

[Article by PRAVDA correspondent N. Bratchikov: "They Searched for Typhoons"]

[Text] The Far Eastern weather ship "Akademik Korolev" has just returned to its wharf at Vladivostok, arriving from the hot latitudes of the Atlantic: for three months it investigated typhoons directly in their "nest," not far from the shores of Cuba.

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Judging from the bronzed faces of the sailors and scientists, decoration of the cabins and the lacework of coral tropheys in the ship's museum, the tropical atmosphere has not yet disappeared. It is also alive in the conversations of people. G. Khloyev, deputy captain for scientific work, states:

"The powerful Gulf Stream is generated in the Atlantic. In many respects it determines the climatic conditions of the northwestern regions of our country. If the temperature at its source is decreased, how will this be reflected in the weather, for example, at Murmansk. One of the principal reasons for such changes is the hurricanes and typhoons which are capable by the mixing of deep waters of cooling the current from two to six degrees Celsius."

"For learning the patterns of such natural phenomena the laboratories of the 'Akademik Korolev' are outfitted with the latest equipment. There are 29 of them on the ship. Oceanologists are investigating the chemical and temperature regimes of the ocean, its waves, currents, color and transparency. Aerologists and meteorologists are 'working' with the air ocean at altitudes up to 35 km. Assisting the weathermen are radars for assisting in the detection of rain and thunderstorms long before their approach to the ship. Data are processed rapidly using an electronic computer."

"Cuban specialists are also interested in the results of our experiments," continues Grigoriy Sergeyevich.

"Indeed, hurricanes inflict an enormous loss on the national economy of the republic. Ten Cuban meteorologists participated with us on this voyage. Usually the parameters of typhoons are studied in safer zones where the wind force does not attain the extreme velocities. But meteorologists are interested more and more not in the results of typhoons, but in the reasons for their generation. On the other hand,

precisely in the heart of storms man will someday be able to act upon the threatening forces of nature."

"How are typhoons generated? For the time being there is much here that is unclear. But in principle the facts are as follows. In the Pacific, Atlantic and Indian Oceans there is a so-called intertropical zone in which the Trades of the northern and southern hemispheres converge. The water vapor rising above the heated ocean surface feeds the low-pressure center developing here and is condensed, releasing heat. It constitutes the energy of a vortex entraining enormous masses of air and water vapor. The principal danger of typhoons is gigantic waves: they rise up to 30 meters in the coastal shallows. The wind attains incredible velocity and the rain comes down in a wall. It is clear that it is not so easy to modify typhoons. Accordingly, scientists of the world are seeking methods for contending with the forces of nature. It is one thing to give a timely warning to inhabitants of the coast and the zone through which the typhoon will pass and another thing to reduce the destructive force of the hurricane itself. It has been experimentally established that by the cannonading of clouds, which in this process are 'seeded' with different aerosols, it is possible to destroy the dense wall surrounding the center of the storm and thus the redistributer of the energy concentrated near the zone of maximum winds."

"This problem is important for the Soviet Union because our Far East is in the immediate neighborhood of a 'nest' of Pacific Ocean typhoons. The trade and fishing fleet is continuing to expand, numerous tracks of ships are being established, including through regions of artificial modification of hurricanes and typhoons, and air routes are being laid out. That is why the 'Tayfun' program is being systematically pursued by Soviet meteorologists. In the Far East there is a scientific fleet whose ships frequently cruise in the ocean. For example, the scientific research ship 'Priboy' worked together with us in the Caribbean Sea. Three others -- the 'Okean,' 'Volna' and 'Priliv' at this time studied the generation of typhoons in the Pacific Ocean. Incidentally, they also recently returned home. An enormous volume of scientific material was accumulated concerning the nature of thunderstorm phenomena."

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DIVING OPERATIONS ON FIRST VOYAGE OF 'VITYAZ''

Moscow PRAVDA in Russian 26 Feb 82 p 6

[Article by V. Yastrebov, expedition head, aboard the scientific research ship "Vityaz'" in the Mediterranean Sea": "Divers Walk on the Bottom"]

[Text] As already reported in PRAVDA, the first voyage of the new scientific research vessel "Vityaz'" is now in progress. It is outfitted with equipment for underwater research. The shipboard hyperbaric complex with a diving bell, the underwater "Argus" manned vehicle and the "Zvuk" underwater unmanned vehicle have made it possible to carry out a geomorphological-geological study of the floor of the Mediterranean Sea in the neighborhood of Cyprus.

This region is one of the remaining parts of the ancient Tethys Ocean, existing 170 million years ago. The shelf part of the island has still been poorly studied.

The expedition and the Cypriot professional geologists, who participated in the work, planned two polygons: near Cape Paphos and Akamas Peninsula. Traditional methods, such as a detailed bathymetric survey of bottom relief, were combined with the submergence of researchers in a diving bell and observations using underwater vehicles.

In the first stage of the expedition nine dives were made with the "Argus" underwater manned vehicle. Doctor S. Elephteriu of the Cypriot Geology Department and I. Shchirkov, a specialist at the Institute of Marine Research and Oceanology, Bulgarian Academy of Sciences, participated in two of these dives. As a result it was possible to make a detailed study of depths from 60 to 450 m. In particular, divers and dredgers took bottom samples for the purpose of seeking supplies of sand on the bottom suitable for construction purposes. This program was carried out at the request of Cypriot geologists. Large supplies of sand were discovered in the neighborhood of Cape Paphos.

It was discovered from the "Argus" underwater vehicle that at the bottom surface of the Mediterranean Sea, the same as in the Red Sea, there are a great number of mysterious openings which are usually arranged in groups. Their origin has not yet been precisely established. But in one of the experiments it could be noted that an immobile creature, externally similar to a hedgehog with long needles, suddenly very friskily disappeared into the opening. The size of the animal precisely corresponded to the size of the opening (2-3 cm in

diameter). Only the tips of the needles remained sticking outside. Earlier they were also observed protruding from the openings, although the animal itself was not seen. Is it possible that such "hedgehogs" are the builders and inhabitants of the openings?

Archeological investigations were also made in the polygons. The remains of an ancient ship, loaded with amphorae and different kinds of earthenware, were discovered and photographed near one of the reefs, not far from the shore. The litter of these objects extends for approximately eight meters on the bottom. They are solidly cemented to the rocks and are covered with algae and sponges.

The investigations of the specialists of the Institute of Oceanology, USSR Academy of Sciences, with the use of the diving bell were the most important. Ten dives were made with the bell, also with the participation of Bulgarian divers trained in oceanology. Investigations were made from the bell at depths from 100 to 165 m. The divers were first compressed in a special pressure chamber aboard the "Vityaz'" to a depth of 150 m and for 24 hours lived in it, adapting to the new environment. After arrival in the Paphos polygon the "Vityaz'" anchored and the divers passed from the living compartment into the bell. The latter was detached from the pressure chamber and was lowered to a depth of 165 m. Then a program was implemented for investigating the region earlier studied by the underwater vehicles. Ground samples were taken on the bottom and a collection of animals was made, especially those which took refuge in the openings.

Specialists of the Institute of Oceanology V. Tutubalin, V. Podymov and A. Yurchik participated in the first diving bell crew. Upon completing work in the polygon, they returned to the bell and were raised aboard the "Vityaz'," after which they entered the pressure chamber for rest. The second crew consisted of Bulgarian and Soviet specialists: N. Dukov, L. Klisurov and V. Tutubalin. On 24 February the crew of the hyperbaric complex successfully underwent decompression.

Now the "Vityaz'" is moving on to a second work region -- the underwater "Horseshoe" archipelago in the eastern Atlantic; the expedition will continue its investigations there.

[This item is accompanied by a sketch map showing the expedition's work region near Cyprus and also the point where the "Vityaz'" was located on 25 February.]

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SHIPBOARD SYSTEMS FOR AUTOMATING OCEANOLOGICAL EXPERIMENT

Leningrad SUDOSTROYENIYE in Russian No 2, Feb 82 pp 39-41

[Article by G. N. Grigor'yev, O. S. Zudin, G. N. Kuklin, N. V. Popenko and L. S. Sitnikov]

[Text] The high cost of operating scientific research ships and the need for increasing the efficiency in carrying out complex, many-sided investigations under an extensive subject-matter program have led to an increasingly broader use of a system for automating experiments in oceanology.

The range of problems to be solved by a shipboard automation system is dependent both on the specialized nature of the investigations carried out (hydrophysical, geophysical, biological, multisided, etc.) and on the ship's displacement, and accordingly, the possibilities for carrying scientific personnel and apparatus. The main theme of the problems to be solved by the scientific research ship may include investigations of interaction between the atmosphere and ocean, gravimetric and magnetometric measurements, survey of underwater relief, study of sea currents and waves, ice observations, investigations of electric fields in the ocean and atmosphere, physicochemical analysis of sea water and rock samples, search for mineral deposits, acoustic, radiophysical and biological investigations. For this reason the automation system on the mentioned scientific research ships must be quite universal.

The shipboard system for automation of experiments must ensure long-term carrying out of investigations from aboard scientific research ships, automated collection and primary processing of data on a real time scale, routine communication between subscribers and the system and its use for implementing control actions on the operating regime, representation of express information on the investigated physical fields and processes (for example, a composite geophysical section), specialized processing for the purpose of obtaining final results in the form of physical parameters of the studied object, diagrams, isoline maps and improved geophysical sections. A computer complex ensures the input of the measurement complexes at the rate of its receipt, processing and storage of experimental data, exchange of data with the subscriber facilities, debugging of programs and solution of background problems in specialized processing, exchange of data with elements of the external memory, output of data to documentation units, automatic checking of the correctness of functioning of all technical facilities together with programmed support.

The shipboard system for automating experiments must ensure automation not only of an experiment carried out directly from aboard a scientific research ship, but also the registry and processing of data obtained from automatic buoy stations, controlled underwater vehicles, self-contained submergible instruments (such as instruments for measuring currents and temperatures, bottom seismic stations, etc.).

Shipboard systems for automating experiments can be classified into several types. The simplest systems contain measurement complexes and units for the automated collection of information and its registry on technical carriers and can also include microcomputers. Such systems are intended for use both on ships with a small displacement as the main automation system and on larger vessels as a self-contained subsystem linked to the main system through technical carriers. The use of a single interface can be considered optimum for such systems. The interface of the International Electrotechnical Commission is coming into ever-increasing use for this purpose for programmable instruments. The introduction of a unified interface will make it easy to modify the system, adapting it to the specific tasks of the experiment.

More complex systems for automating experiments include an electronic computer which ensures not only control of the subsystem for the collection of information through the corresponding interface and its primary processing (filtering, elimination of noise, subtraction of the background, editing programs, change of formats, etc.), but also elements for specialized data processing in order to ensure routine monitoring of the experimental result.

The units for the registry and display of the arriving and processed information form part of the peripheral equipment of the computer directly or through the instrument (nonmachine) line and controller. Such units mandatorily must include curve plotters and panels with screens for the output of alphabetical-digital and graphic information. One of the necessary functions of such systems is navigational support of expeditionary work.

Finally, the most complex systems for automating experiments contain electronic computers ensuring scientific processing of the data in the volume of the program of the experiment (voyage) being carried out. The system constitutes a multiply connected hierarchical structure of subsystems of the shipboard computation center and the subsystems for the collection and preliminary processing of data containing micro- or minicomputers and coupled to the computation center directly or through technical carriers. A mandatory requirement is the compatibility of carriers of shipboard systems of all classes and the on-shore computation center, outfitted with a high-capacity electronic computer. This ensures the possibility of processing of data obtained in any system by ship systems for automating experiments of higher classes.

The shipboard system for automating experiments in general must be constructed on the basis of standard unified technical and programming components for ensuring the possibility of its further expansion or the replacement of individual parts.

The standard structure of a shipboard automated system for automating experiments can be represented in the form shown in Fig. 1. The system consists of four parts and is intended for multisided oceanological investigations on

oceangoing ships with a high tonnage. Accordingly, the specialized measurement complexes include the entire range of instruments ensuring the collection of the most diversified experimental data. The information collected from these instruments in the form of electric signals is fed through secondary converters and their interface elements to the nonmachine line. The exchange of information into the lines is accomplished by a controller through which the data from the line are fed to an electronic computer for preliminary processing.

The units combined by the nonmachine line form a subsystem for the collection and registry of information. The data arriving from the measurement complexes are transformed into the code and format adopted for use in the interface through which the line passes. Also connected to the latter through the interface elements are units for the visualization, registry and storage of data. As a result there is a broadening of the functional possibilities of the subsystem for data collection, which enables the researcher routinely to evaluate the results on the display, monitor these results by means of an oscillograph or enter the data into a cassette storage unit for subsequent processing. The specific makeup of the apparatus used in this experiment is completely fixed by the program and the controller, which in addition to the control of the flow of information through the line must ensure an interconnection of the nonmachine line and the computer for preliminary processing.

The program ensuring this connection is stored in an electronic computer, for which a corresponding part of the memory volume must be allocated. However, the performance of the controller function requires only from 5 to 20% of the electronic computer capacity, which makes it possible to use the remaining part for organizing preliminary processing at a real time scale and ensuring a data base. In registry use is made of an analog-digital printout unit, puncher, elements for storage on magnetic disks, etc. connected to the common electronic computer bus. The course of the experiment is monitored by means of a quasigraphic display, which by means of dots constructs very simple curves using the results of the preliminary processing. A group operations processor should be connected to the common bus in certain cases for discharging the main processor.

The routine processing of data makes it possible to monitor the exp riment, evaluate its course and adopt a decision if a repetition is required in the event that the experiment is unsuccessful. The latter is especially important for shipboard systems for automating experiments since under marine conditions the duplication of an experiment requires great material expenditures and as time passes it may be impossible, for example, if the scientific research ship leaves the particular region.

The great volume of data from the outputs of the great many measurement instruments used in a specific experiment does not make possible the complete processing of all the information by means of the preliminary processing computer and its representation in final form. Accordingly, along the intermachine communication line the masses of prepared data (the results of preliminary processing) are fed to a second computer which performs specialized processing of the experimental data and solves auxiliary problems in a background regime. The second electronic computer receives the next mass of data upon interrogation,

which can be fed from any of the electronic computers. If current processing continues in a real time regime, the interrogation from the preliminary processing electronic computer is a command interruption by which the specialized electronic computer ceases operation and serves as a subsystem for data collection. When the specialized electronic computer is ready for background processing it sends an interrogation to the preliminary processing electronic computer and this begins a readout of the data prepared for processing.

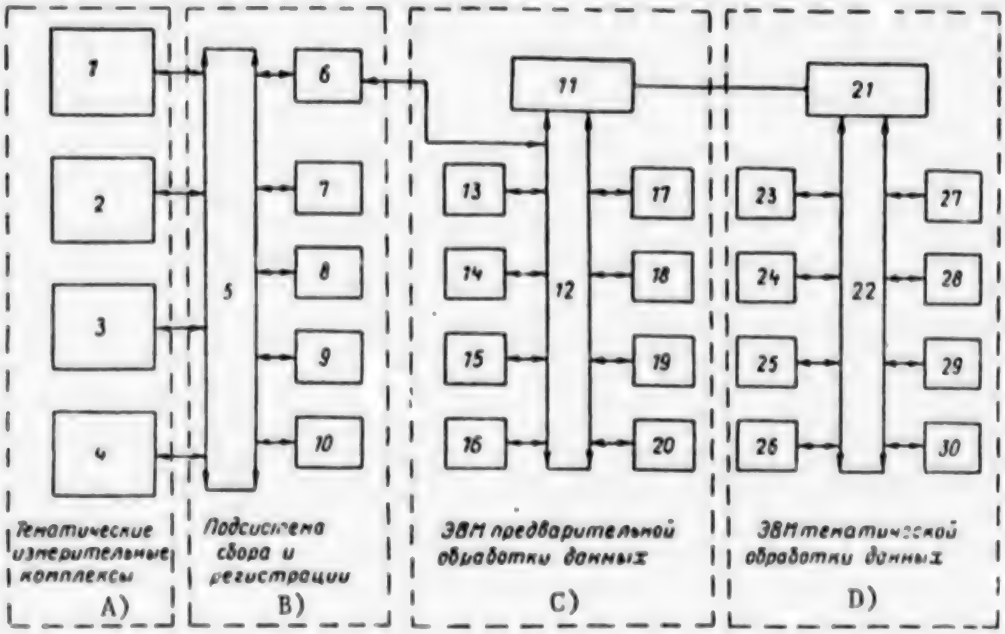

Fig. 1. Example of standard structure of shipboard system for automating experiment. 1, 2, 3, 4) hydrophysical, hydrochemical, geophysical, meteorological specialized measurement complexes respectively; 5) nonmachine line; 6) controller; 7) display; 8) cassette unit for storage on magnetic tape; 9) facsimile recorder; 10) oscillograph; 11, 21) central processor; 12, 22) machine line; 13, 27) analog-digital printout unit; 14) monitor; 15) curve plotter; 16) quasigraphic display; 17, 25) photoreadout; 18) puncher; 19, 30) unit for storage on magnetic disk; 20, 29) unit for storage on magnetic tape; 23) unit for input of graphic information; 24) precise curve plotter; 26) graphic display with unit for producing hard copy; 28) operator's display.

KEY:

A) Specialized measurement complexes
B) Collection and registry subsystem
C) Electronic computer for preliminary processing of data
D) Specialized data processing computer

Information usually processed in a background regime is introduced through the periphery of the specialized computer for solving auxiliary problems. This makes it possible in advance to debug the experimental programs, to check methods, to

solve problems not directly related to an experiment currently being carried out, such as model problems.

The principal shortcoming of the considered variant of a shipboard system is the absence of a stand-by computer, especially for the preliminary processing computer. The need for a stand-by is dictated by the specific conditions under which the shipboard system for automating an experiment operates. The limitation on the resources of the electronic computer due to small areas, severe operational conditions and an insignificant number of qualified specialists -- all this leads to an increase in the number of failures. Any failure in the preliminary processing computer leads to a disruption in obtaining primary information, which frequently becomes inadmissible.

The possibility of a stand-by arrangement is taken into account in the shipboard system for automating an experiment whose structural diagram is shown in Fig. 2. It is difficult to have a breakdown into subsystems as in Fig. 1 in this structure because the functions of the different units in this case are considerably expanded and can change. A considerable part of the tasks of collection, registry and preliminary processing of data is shifted to the intelligent terminals, having a sufficient computation capability and having a well-developed periphery. The specialized processing computer in the event of failure of the preliminary processing computer takes over the functions of the latter. The system with the stand-by capability has two regimes: normal and emergency operation.

We will examine system operation (Fig. 2) in a normal regime when there are no failures in any of the devices. The specialized measurement complexes are connected to the intelligent terminals having a panel, screen, processor, storage units on magnetic minicassettes or flexible disks, built-in printout devices, plotters, as well as an input-output channel meeting the requirements of the IEC interface for programmable instruments. Due to the possibility of processing the experimental data with intelligent terminals, their display on a screen or using curve plotters, a high percentage of the problems can be solved by the terminals. At the present time 70-80% of the local experiments can be serviced by intelligent terminals and the possibilities afforded by them will constantly increase, especially with the introduction of microprocessors into their structure.

Specialized measurement complexes can be connected to the intelligent terminals in groups, which enables each terminal to service several experiments parallely, and in the event of any malfunctioning will connect the complexes serviced by them to other terminals. Thus, a solution is obtained for the standby problem at a lower level.

When carrying out experiments in which "semantic" processing algorithms are required or there is a flow of high-intensity information (in the analysis of turbulence, seismic or acoustic investigations) the data obtained from specific measurement complexes are fed through an individual controller and input-output expander directly to electronic computer I for preliminary processing. The masses of data prepared in electronic computer I are fed to electronic computer II through a direct access channel. Computer II is connected only to

computer I and solves the problems of specialized data processing. The functioning of both computers in a normal regime differs little from their functioning (described above) in the system shown in Fig. 1.

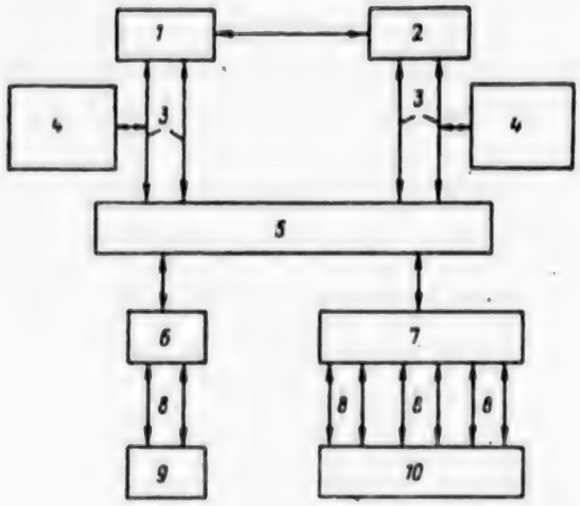

Fig. 2. Shipboard system for automating scientific experiments with stand-by capability. 1) electronic computer I; 2) electronic computer II; 3) machine (computer) lines; 4) peripheral devices; 5) widener of computer line with switch; 6) controller; 7) intelligent terminals; 8) nonmachine lines; 9, 10) specific and specialized measurement complexes respectively.

As the nonmachine line to which the specialized measurement complexes are connected it is possible to use a line fabricated in conformity to the "KAMAK" standard or in conformity to the IEC interface for programmable instruments.

In the event of failure of computer I the system is switched to an emergency regime whose purpose is ensuring the collection and registry of data using computer II. The switching element connects the output of the input-output widener to computer II, which proceeds to emergency servicing of the collection subsystem. In this process computer II may completely cease all operations unrelated to the collection of data or may allocate only part of its resources in the necessary volume to take care of the emergency situation. It is evident that the first variant is less efficient but considerably simpler because it does not require the development of complex special programmed support and leads only to replacement of one program by another. The choice of the specific variant is dependent on such factors as the capabilities of the used electronic computers, algorithms and volumes of processed experimental data, the possibility of developing complex programmed support, and must be solved in each specific case.

The shipboard system for automating a scientific experiment aboard the scientific research ship "Akademik Mstislav Keldysh" corresponds to the block diagram shown in Fig. 2. The system was created as a result of the joint work

of Soviet and Finnish specialists and constitutes a unique hierarchical distributed structure having no analogues in world oceanological practice. The system includes specialized measurement complexes, 7 laboratory computers of the Phillips Company of the PC 4401/10 type with a memory capacity of 64 000 words each, 3 "KAMAK" elements, and also a computer complex (photograph, Fig. 3 [not reproduced here]) based on two small computers of the Phillips Company, type P857 (length of words -- 16 bits, memory unit access time -- 700 nanosec, memory unit capacity -- 128 000 words) with a large set of peripheral devices.

The measurement complexes connected directly to the system computer complex include:
-- an integral navigation system ensuring the carrying out of research work in the open sea containing a P857m electronic computer and peripheral and navigational devices linked to it:
-- ELAK NVK and ELAK ENIF research echo sounders;
-- "Väisälä Midas 320" automatic synoptic station.

The laboratory computers are connected to:
-- NBIS vertical sounding equipment (conductivity, temperature, dissolved oxygen, pH, turbidity sensors) installed in a "Rozett" system and a laboratory salinometer -- in the hydrological laboratory;
-- NBIS horizontal profiling equipment and a "Tekhnikon" continuously operating automatic analyzer -- in the hydrochemical laboratory.

In addition, on shipboard there are a number of individual analyzers and measurement instruments, as well as equipment for the preliminary processing of geological biological and water samples.

The system ensures the automated collection of data when carrying out a wide range of experiments in different specialized fields, their registry, preliminary processing, display, forming a data base and specialized processing. The existence of the system sharply increases the effectiveness of oceanological investigations, makes it possible to carry out a controllable experiment, complex collection and processing of data on different oceanological fields and processes.

It must be noted in conclusion that the described structures in systems for automating an oceanological experiment are quite universal since the connection of other programmable instruments to the nonmachine lines instead of oceanological measurement complexes will make it possible to use systems for the automation of an experiment in other branches of science and production as well.

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FIRST VOYAGE OF 'AKADEMIK MSTISLAV KELDYSH'

Moscow ZEMLYA I VSELENNAYA in Russian No 1, Jan-Feb 82 pp 62-64

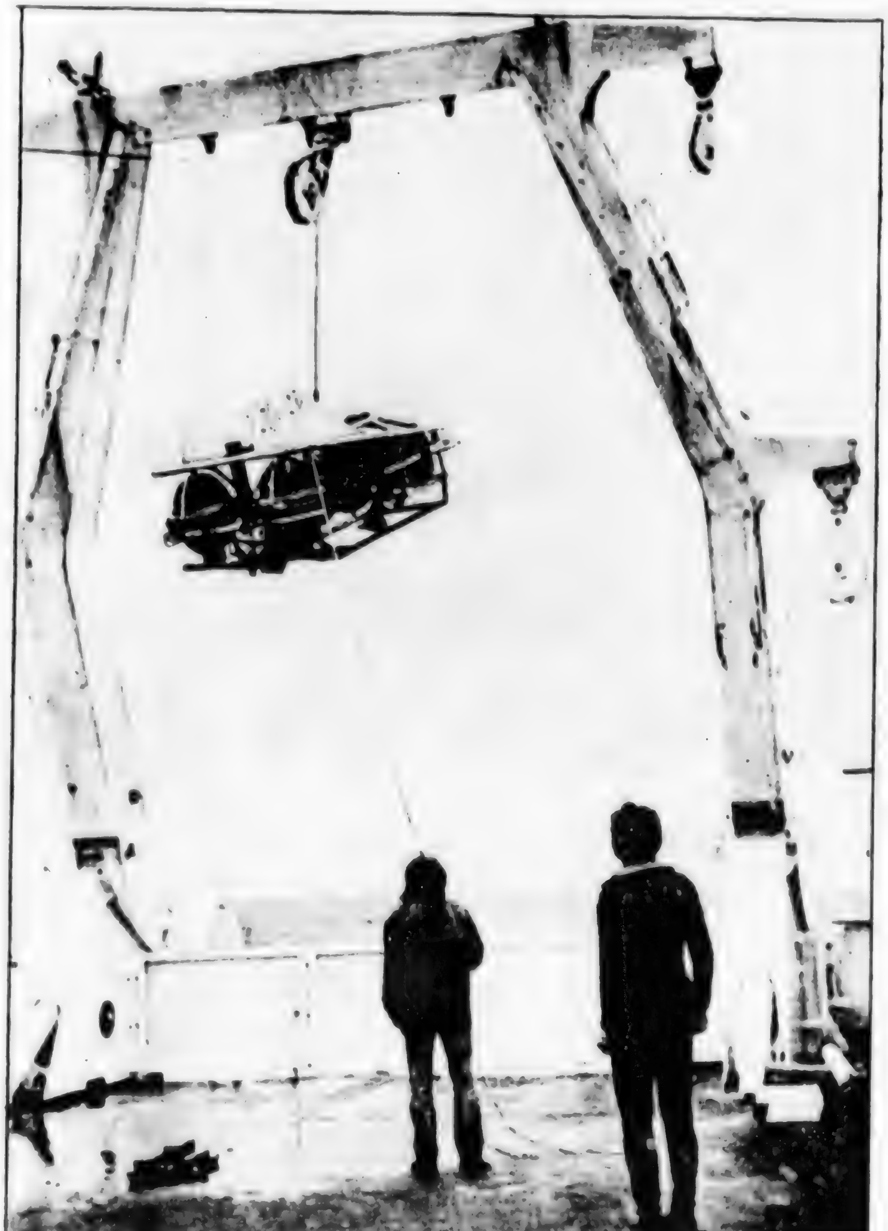
[Article by V. I. Voytov, expedition chief]

[Text] The Baltic and North Seas, the Kiel Canal and the straits lie behind. On 3 March 1981 the scientific research ship "Akademik Mstislav Keldysh" for the first time entered the expanses of the Atlantic. This was the beginning of the biography of a new scientific ship...

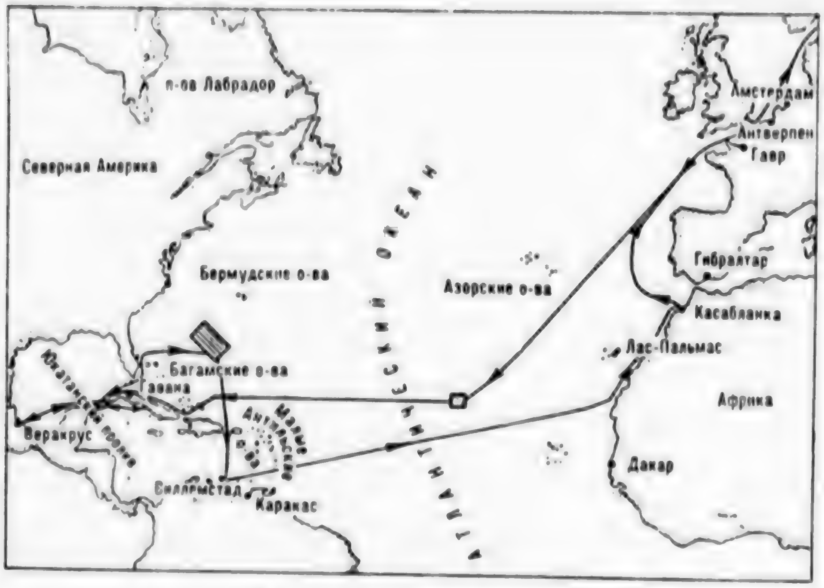
The "Akademik Mstislav Keldysh" is one of the few ships in the world which was designed and constructed specially for scientific investigations in the ocean. This is indicated by the ship's architecture. The superstructure rises at midships, displaced a little toward the prow. The superstructure contains ample laboratories, halls and wardrooms. The vessel's asymmetry is conspicuous. On the port side the superstructure is massive; the prow and stern decks are less crowded. A hangar and apparatus for lowering a manned underwater vehicle and towed instrumentation alone are situated closer to the stern. The starboard side is the working side on the "Akademik Mstislav Keldysh." Winches and booms are installed here on the ramps connecting the decks; these are used in lowering the oceanological instruments over the side. The underwater part of the ship's hull, resembling the contours of a racing yacht, is of an unusual configuration. The beveled stern also has an unusual appearance. Such a configuration was adopted in part due to the "Aquamaster" rudder control apparatus installed there; it ensures the turning of the screw by 360°. Another rudder control apparatus of the "screw in a pipe" type is situated at the prow. The rudder control apparatus enables the ship to make different maneuvers, such as turning about its axis in place, and in addition, creates such a support that the "Akademik Mstislav Keldysh," when exposed broadsides to a wind of force 6, is able to maintain itself in place.

It is noteworthy that the first voyage of the new scientific research ship, with a displacement of 6290 tons (its length is 122.3 m and its width is 17.8 m), began exactly 60 years after V. I. Lenin signed a decree which gave a powerful stimulus to the development of oceanological research in our country. The first section of the decree spoke of the need for creating a marine floating scientific institute. It appears that this idea has found full embodiment in the scientific research ship "Akademik Mstislav Keldysh," in essence being a real floating institute. The ship has 16 fixed and 4 containerized laboratories

which can be "stuffed" with apparatus for a stipulated branch of research and which by means of cranes can be moved to any place on the prow and stern decks. In some of the stationary laboratories there are electronic computers which are connected by two-way communication lines with the ship's main computation center. Getting ahead of ourselves, we can say that the availability of modern computers has made possible the full processing and analysis of meteorological, hydrophysical and in part geophysical information long prior to the ending of the voyage.



On ship's deck. Raising of the towed "Zvuk-4M" apparatus. Photo taken by V. F. Simonov.



Track of "Akademik Mstislav Keldysh." The shaded rectangles represent polygons.

One of the principal tasks was the testing of the latest research equipment, auxiliary mechanisms and the vessel itself under the conditions of a prolonged oceanic voyage. This problem was solved in the first stage of the expedition, in the central Atlantic. The ship proved to be extremely seaworthy. The highly modern integral navigational system aboard the ship made it possible to carry out different highly precise oceanological surveys. Many instrument complexes were put into operation, as well as the auxiliary mechanisms necessary for solving the scientific problems of the voyage.

By agreement between the Academies of Sciences of the USSR and the Republic of Cuba, during the voyage joint Soviet-Cuban investigations were carried out. Together with Cuban specialists extensive oceanological observations were made in Yucatan Channel and in the Caribbean Sea. An echo sounding survey was used for geological-geomorphological investigation of these areas. Exploratory work was carried out with the "Zvuk-4M" towed underwater apparatus with television and photographic apparatus. Samples of bottom sediments were taken with corers and dredges. These investigations yielded new material on relief of the sea floor and the patterns of distribution of sediments and benthos organisms. It was possible to make extremely interesting observations in the small Cuban gulf Cazones, where an upwelling was discovered. As is well known, sea fishing develops in the waters of an upwelling, rich in plankton.

The next stage in the expedition was a hydrometeorological survey in the region of the "Bermuda Triangle." It was, indeed, the principal scientific task of the voyage since it was directly related to the extremely timely hydrometeorological "Razrezy" ("Sections") program. This program is the first practical step in formulating the physical principles of methods for long- and superlong-range weather forecasting and the creation of a theory of climate. The draft of the "Razrezy" program was prepared under the direction of Academician G. I. Marchuk. According to this program, during 1981-1985 plans call for expeditionary work in several

energy-active zones in the ocean where heat is intensively transmitted to the ocean from the atmosphere. Four such zones have been defined in the Atlantic: Newfoundland, Norwegian, Bermuda and Tropical. The Institute of Oceanology of the USSR Academy of Sciences was assigned the Bermuda zone, in which it is necessary to carry out meteorological, aerological, radiation and hydrophysical investigations. The full program will be carried out by a group of ships, whereas the abbreviated program will be carried out by only one. This is the nature of the investigation which was carried out during the period 23 April-4 May 1981 in the Bermuda polygon.

The results of the meteorological observations made it possible to study the temporal and spatial variability of the principal meteorological elements and to compute the heat flows. Fluctuation sensors mounted on an extensible prow boom were used in direct measurements of flows of heat, moisture and momentum. Optical methods yielded considerable information on the physical properties of the atmosphere. With respect to hydrophysical measurements, they assisted in investigations of the eddy structure of the ocean, in many respects determining the hydrological conditions in the neighborhood of Bermuda. In other words, all the initial data were obtained which are needed for further study of interaction between the ocean and the atmosphere...

The Bermuda polygon is situated in the western part of the Sargasso Sea. Yellow-brown concentrations of unique Sargasso algae float here in the bright blue water. The seamen accompanying Columbus said that the Sargasso Sea is most similar to a green meadow and the legend later appeared that propellor-driven ships could not navigate these waters due to the abundance of algae. But it is important to see this "wonder" with one's own eyes! In actuality, instead of a "continuous meadow," only small spots and bands formed by algae are visible at the surface. These "patches," similar to clumps of hay, are completely safe for ships and will not be entangled in screws...

A geological-geomorphological survey gave highly interesting results. For example, on the western flank of the Mid-Atlantic Ridge a detailed study was made of an unnamed submarine volcano. The participants on the expedition, using the towed "Zvuk-4M" apparatus, took geological samples and made an echo sounding survey of the volcano (it was proposed that it be named "Akademik Keldysh Seamount."

The same type of work was carried out around the Am ere Seamount, which during recent years has attracted great attention. Because of underwater photographs of this seamount which have appeared in the press some scientists have postulated that the details at its peak are surprisingly similar to ruins left by ancient man. A great number of photographs and videofilms were obtained and these revealed to us still more fragments of formations resembling the residue of ancient structures. And although we will soberly look at these things, while regarding all these geometrically true outlines to be a simple caprice of nature, nevertheless, only after man descends to Ampere peak will there be a final solution of this problem.

The "Akademik Mstislav Keldysh" visited many countries, but the voyage participants will especially remember their Mexican excursion. Sixty kilometers to the north of the port of Vera Cruz there are remarkable monuments of ancient Mexican architecture -- pyramids of the Totonac indians, at one time subjugated by the Aztecs. When

Cortes with a detachment of Spanish conquistadores undertook their march to the ancient capital of the Aztecs, Tenochtitlan, the Totonacs supported the Spaniards in the hope that they would help in liberating them from the Aztecs. The peaceful Totanac tribes were famed as builders and agriculturalists: under the blazing sun they cultivated many plants, such as corn, which from there spread throughout the world. They created a splendid architectural ensemble of nine pyramids. The Spaniards, seeing the pyramids for the first time, visualized that these were structures of pure silver because their walls sparkled so in the sun's rays. In actuality, the pyramids were simply encrusted with mother-of-pearl shells...

The "Akademik Mstislav Keldysh" returned to the motherland in mid-June 1981.

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THEORETICAL PROBLEMS IN OCEANIC GEOLOGY

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[Article by A. V. Peyve and Yu. M. Pushcharovskiy]

[Text]

Biographical data on A. V. Peyve. Aleksandr Vol'demarovich Peyve, academician, director of the Geological Institute, USSR Academy of Sciences, author of fundamental works in the field of study of structures in the earth's crust, its movements and evolution. PRIRODA has published the following articles: "Ophiolites and the Earth's Crust" (No 2, 1974); "Geology of Today and Tomorrow" (No 6, 1977); "Mobilism and Tectonic Stratification of the Lithosphere" (jointly with V. G. Trifonov, No 8, 1981). Winner of USSR State Prizes. Hero of Socialist Labor.

Biographical data on Yuriy Mikhaylovich Pushcharovskiy, corresponding member, USSR Academy of Sciences, professor, head of Tectonics of Circumocean Zones Laboratory of the same institute. Author of a number of tectonic maps of major regions of the earth and several monographs, including: VVEDENIYE V TEKTONIKU TIKHOOKEANSKOGO SEGMENTA ZEMLI (Introduction to Tectonics of the Pacific Ocean Segment of the Earth), Moscow, Nauka, 1972, as well as many articles in the journal PRIRODA. Winner of the USSR State Prize, deputy chief editor of the journal PRIRODA.

Only several decades ago concepts concerning geology of the oceans were very approximate. This knowledge began to develop after the Second World War when sea expeditions began to be organized systematically in our country and abroad.

The investigations which we carried out yielded abundant material primarily on the bottom relief of the world ocean. Data on relief of the earth's surface were always important for geology because to one degree or another they make it possible

to detect structural elements and zones of which the earth's crust consists, such as folded (mountainous) zones and platforms (lowland regions) determining the structure of the continents. But data on relief of the ocean floor for geological constructions have a very exceptional importance because here the relief elements and elements of tectonic structure usually coincide. As a result of study of bottom relief and generalization of world material specialists in the Soviet Union have published a whole series of bathymetric charts showing the great complexity of structure of the ocean and sea floor. The resulting pattern has graphically shown that the ocean floor is not inert but tectonically mobile, that in the course of its structural development different rises occur, bottom subsidence takes place and faults are formed. With respect to the character of combination of tectonic elements the oceans as a whole and their individual large regions differ from one another. Such a representation came to replace the idea of stability and rigidity of structure of the ocean floor, in its time giving rise to a term introduced in 1955 by D. Firebridge -- thalassocraton (from the Greek -- oceanic fortress), which now has already fallen into disuse.

Geophysical investigations have been carried out in considerable volume parallel with study of bottom relief. They are divided into two groups -- deep seismic sounding and multisided study of geophysical fields (gravimetric, magnetic, geothermal). These investigations created an exceedingly important basis for geological constructions -- providing some idea concerning geophysical inhomogeneities of the oceanic crust and its individual layers not only vertically, but also, it was found, horizontally. These ideas led many geologists to the fact that deep masses here move considerable distances and that horizontal tectonic movements are clearly manifested in bottom structure.

Geological investigations were concentrated on study of the mineralogical composition and tectonic deformations of layers of the earth's oceanic crust and the mantle rocks underlying it. Whereas for studying the sedimentary layer (first layer of the oceanic crust) and the upper part of its basalt substrate (second layer of the oceanic crust) it has been drilling work, carri d out from the American drilling ship "Glomar Challenger" which has been of the greatest importance (during the last few years on an international basis with the participation of the USSR Academy of Sciences), for an investigation of the rocks which are situated in the lower parts of the second layer and also rocks of the third layer and mantle it is the sampling of rocks by means of dredges on steep scarps which has been of the greatest importance. Here it is possible to recover rocks at different levels and obtain some idea concerning the vertical structure of the crust. In this sense the materials obtained by Soviet expeditions in fault zones intersecting the East Pacific Ocean Rise, on submarine scarps in the northwestern part of the Pacific Ocean, in the abyssal Mariana and Yap trenches, in the region surrounding the East Indian Ocean Rise, in Owen fault in the northern part of the Indian Ocean and in a number of fault zones of the North Atlantic are of exceptional interest.

The processing of the collected materials made it possible to introduce clarity into our understanding of the geological section of deep oceanic layers.

Ultrabasic rocks of the upper mantle, ultrabasites, lie at the base of the earth's crust. They are poorest in silicic acid, are enriched with magnesium and consist of such ferromagnesian minerals as olivine and pyroxene. The different relationships between olivine and varieties of pyroxene determine if the ultrabasic rocks are of

one type or another: dunites, peridotites and pyroxenites. Peridotites, in turn, can be classified as harzburgites, lherzolites and wehrlites. Peridotites are most widespread among the rocks detected in the ocean mantle. Mantle rocks are substantially modified, deformed and fragmented. In some cases they are greatly uplifted along major faults. For example, according to data from the 19th voyage of the "Akademik Vernadskiy," in Owen fault the upper mantle rocks made up a wall with a height of 3 km.

Above the ultrabasites in the mantle in ordinary sections there are rocks which are no longer ultrabasic, but of a basic composition. They are characterized by a somewhat higher content of silicic acid, such as gabbro, and also metamorphic (transformed and recrystallized) rocks, especially amphibolites. The development of these rocks is a result of transformation of basic, in part ultrabasic magmatic rocks and to a certain degree of sedimentary layers. This varied complex is the lowest layer of the oceanic crust -- the third layer. Above it there is a second layer whose main component is basaltoids, primarily tholeiitic basalts. This variety of basalts is characterized by a relatively low Na_2O and K_2O content. Due to their petrochemical characteristics they are frequently called "primitive basalts." Basalts with a relatively high content of alkaline metals are called alkaline. They are also present in the crustal section.

During the time of the 23d voyage of the scientific research ship "Dmitriy Mendeleyev," employing data on the composition of rocks recovered by dredges from scarps in the Hess Rise in the Pacific Ocean, it was possible to construct a section of the second layer of the oceanic crust with a thickness of 2.5 km. Atop the basalts in the central regions of the oceans there are abyssal sedimentary deposits -- clayey, whose age is not greater than 150 million years. In different places the thickness of this layer varies, but in general is small and rarely exceeds 1000 m. The stratum of sedimentary deposits, on the basis of its content of microorganisms, is broken down into age-comparable layers in the entire world ocean, which is now a reliable basis for a global correlation of geological phenomena.

The total thickness of all three layers (that is, the thickness of the crust) is the same. Under the abyssal plains, that is, those situated deep below the water, it is only 6-8 km. This is 5-6 times less than the thickness of the crust on the continents.

All these data created an excellent basis for deeper geological investigations of the sea and ocean floor, which are now being devoted considerable attention by Soviet geology.

Principal Structural Categories of the Earth

The oceans and continents, differing with respect to type of crust, are the two principal structural categories of the earth. There are also zones in which a continental or oceanic earth's crust is now being formed, with its accretion transpiring. Along the continental margins, in zones of joining of the oceanic and continental crust, the sialic layer (the external layer of the earth's crust, consisting primarily of Si and Al) is increasing, whereas in "outflow," dilatation, or so-called "spreading" zones of mafic (consisting primarily of Mg and Fe) or sialic masses a new oceanic crust is being formed.

Crustal accretion is a complex and multiphase process; the tectonic crowding of rock masses plays a major role in it. It has been adequately studied on the continents and in the zones of their joining with the oceans, as well as in regions where the chains of islands are elongated in an arc -- island arcs. Far less is known about the mechanism of accretion of the mafic crust, but it can scarcely be doubted that its growth is occurring as a result of horizontal tectonic underflow, "crowding" and rising of the mafic material.

Many geologists, adhering to the concepts of mobilism, still call the process of accretion of the continental crust by the term "geosynclinal process" without regard to the fact that the geosynclinal concept rests on the contraction hypothesis, according to which the earth is cooling, which leads to its compression and the bending of rocks into folds. This hypothesis no longer is enjoying recognition among geologists. Accordingly, the accepted basis of the geosynclinal theory, based on the classical fixism doctrine, must be reexamined.

In any major, young or ancient folded structure, such as the well-known Urals Range, Alpine mountain zone, Tien Shan, Mongolian-Okhotsk zone, Sikhote Alin', etc. geological methods have revealed several mineralogical-structural complexes successively alternating with each other in time. The lower of these is the ophiolitic complex. It was formed by ultrabasites, various types of gabbroids and amphibolites covering them, highly modified tholeiitic basalts and also siliceous and other rocks forming under abyssal conditions. These are in fact analogues of layers of the modern oceanic crust and its substrate. This conclusion, formulated at the Geological Institute, USSR Academy of Sciences as early as 1969, is of a fundamental character in modern mobilistic tectonic theory. Since within the limits of the modern continents it is possible to see fragments of the ancient oceanic crust, it is completely natural to conclude that in the corresponding regions there were initially regions with an oceanic crustal structure.

What occurred with these regions later? How did their fragments appear within the continents? Modern tectonics answers these quesions unambiguously: with the passage of time a granite-metamorphic layer was formed in some way or another in such regions. This process was prolonged and could take several hundreds of millions of years. Two phases are discriminated in it. During the first phase, which was most protracted, a mineralogical-structural complex was formed following the oceanic complex; this phase was extremely diversified in composition. It also contained volcanites, but of a different type, primarily of intermediate composition (andesites); it also was characterized by the presence of acidic lavas (dacites, liparites) and sedimentary rocks (graywackes, clay shales, tuffs). In these, especially in the upper parts of the section, it is rather common to encounter rhythmically alternating strata such as flysch and so-called lower molasse. Among the sedimentary rocks there are also typical strata of avalanche sedimentation. These are turbidites, deposits of turbidity currents moving at a great velocity.

In this intricate complex of volcanic and sedimentary rocks different intrusions of magmatic rocks are already appearing, including granites poor in potassium -- plagiogranites. Their injection is the main indicator of

the already transpiring process of formation of a granite-metamorphic layer. The latter attains the most complete development under the continents where its thickness is 15-20 km. The rocks of this second complex occur zonally. This zonality corresponds to that which is observed at the present time in zones of development of island arcs, marginal seas and abyssal trenches. It can be assumed that in the very remote geological past, about a billion years ago, tectonic conditions existed locally on the earth, in general similar to those which are characteristic for the present-day active continental margins where the structural complexes of island arcs were formed. The earth's crust in such regions is characterized by a complex, spotty structure where there are sectors with oceanic, suboceanic and subcontinental crusts, differing from one another in degree of development or absence of a granite-metamorphic layer, thickness and composition of the sedimentary and volcanic layers, features of structure of the deep parts of the crust and thickness of the earth's crust as a whole. Tectonically these are extremely dynamic regions of the earth, regions which are in the process of formation of the continental crust. If here there are blocks with a crust typical for the continents, they were detached from the continents, moved and were entrained in the process of transformation of the oceanic crust into a continental crust. The so-called passive margins of the continents, characteristic for the framing of the Atlantic, are also places of accretion of the continental crust. After the accumulation of extremely thick sedimentary strata along these margins, their crumpling into folds and metamorphism, a new granite-metamorphic layer appears.

In the last phase of transformation of the oceanic crust into a continental crust the masses of the earth's crust are intensively crowded together as a result of horizontal compression, potassic granites typical of the continents are injected and characteristic specific geological complexes are formed (coarse continental strata, extensive volcanic-plutonic zones). The processes of pushing together of the crust and granitization finally lead to the formation of monolithically bonded continental masses with a typically continental earth's crust characterized everywhere by the occurrence of a mature granite-metamorphic layer.

The forming continents are not constant and eternal structural formations on the earth. They develop tectonically and form structural formations and geological-mineralogical complexes of a special character characteristic only of them. The principal basis of the continents is the ancient platforms, forming 1-1.7 billion years ago. Soviet geologists have made a major contribution to study of the tectonics of platforms. Studies have been made of the structure of the sedimentary cover (mantle) and the crystalline basement on which the sedimentary cover rests. The cover of the platforms, such as the East European and Siberian Platforms, is formed slowly, but finally major and diversified structural forms are formed in it with characteristic strata of rocks controlling the occurrence of many types of minerals, including petroleum, fuel gas, coal, phosphorites, salts, some metallic minerals, etc.

With respect to the structure of the basement of ancient platforms, during recent years sensational results have been obtained. It was found that in the formation of its highly complex structure a very important role was played by

horizontal compression with the slipping of thickened and thin plates relative to one another. During the drilling of the Kola superdeep borehole, penetrating about 11 km through the crystalline basement, tectonic breccias were discovered at a number of levels -- evidence of horizontal movements.

The continents were always broken by faults along which their parts can move far from one another. Depressions with an oceanic crust are formed between them.

Thus, it is possible to discriminate three principal stages in evolution of the earth's crust of the continents -- oceanic, transitional and continental proper. The transitional stage in the continental margins with the island arcs conforms to the geosynclinal stage in the full sense of this word. On the passive margins (without the island arcs) in this case it can be equated to a myogeosynclinal stage (that is, weakly geosynclinal).

Modern Mobilism

In 1980 a hundred years had passed since the birth of the outstanding scientist Alfred Wegener, who 70 years ago postulated the splitting of the ancient continental masses, their drift and the formation of oceans between their parts. Although continental drift has now received numerous confirmations, its mechanism and causes still remain mysterious.

In the late 1960's the mobilistic concept of the tectonics of lithospheric plates was proposed by oceanologists and geophysicists for explaining such a mechanism. According to this concept, the earth's lithosphere, situated above the asthenosphere, broke down into several plates. The latter extend over extensive regions of the oceans or the oceans and continents simultaneously. The plates move from the axial zones of the mid-oceanic ridges in opposite directions above the softened asthenosphere until reaching the abyssal trenches, locally situated at the margins of the oceans where the lithospheric plates "dive," being sucked into the mantle. At the same time, in the axial zone of the mid-oceanic ridges basaltic magmas constantly rise, which continuously generate plates moving away from the ridge from the rear side. Something similar to a conveyer system is the result. The lithospheric plates observed in this case must behave as homogeneous rigid bodies having a gigantic area and a very small thickness -- under the oceans tens, and under the continents not more than several hundreds of kilometers.

Many of those who accept such a geodynamic model feel that precisely it and only it develops Wegener mobilism.

We must give its due to this model, which graphically, simply, and from the point of view of mechanics easily explains the development of some tectonic-magmatic processes in the lithosphere. However, the model is adapted primarily for explaining the tectonics of the oceans. But with respect to the continents, in particular, regions with a complex structure, developing over a prolonged period of geological time, it is quite difficult to apply this model. As indicated by new facts concerning deformations of the oceanic earth's

crust, for the oceans as well the concept does not always "fit." However, it must be admitted that in the development of the modern science of mobilism the concept of tectonics of plates has played an exceptionally important role.

In what direction is modern mobilism developing? We will return to the main principle of the concept of the tectonics of plates -- the opposition of the lithosphere and asthenosphere. The lithosphere is the earth's upper shell, consisting, presumably, of rigid, solid and rheologically (rheology is the science of flowability of matter) homogeneous gigantic, but relatively thin plates. The asthenosphere has a reduced viscosity. It is assumed that the rocks in the asthenosphere are partially molten. The properties of flowability of the asthenosphere determine the possibility of convective currents in the earth's mantle, causing movement of lithospheric plates.

Recently, however, data have been obtained showing that the lithosphere is by no means homogeneous, but is stratified into individual plates differing with respect to physical, including rheological properties. The discontinuities of the plates are zones where the rock masses move in a horizontal direction. Thus, horizontal movement occurs not only through the asthenosphere, but also through many other layers also of relatively reduced viscosity, that is, along tectonic discontinuities situated within the lithosphere. These data considerably complicate the pattern of movement in the scheme of tectonics of plates.

The lithosphere occupies the earth's crust and the upper part of the earth's mantle. Horizontal movements -- shears -- occur both in the mantle and in the crust. In all the mountain systems of the Alpine zone, be it the Himalayas, Pamir, Caucasus or Alps, in many bordering regions of the Pacific Ocean, in the Urals, in the Appalachians, in Scandinavia and in many other places, there are rock masses torn from their initial positions and moved for considerable distances; these are tectonic plates, thrust sheets, mass overthrusts or covers. We call such masses crustal allochthones if they occupy the upper layers of the lithosphere or mantle allochthones if they occupy the mantle. These displacements of rock masses constitute the principal geological proof of horizontal movements.

Many displacements with a large amplitude (such as those along the San Andreas fault in California) were formed as a result of the rupturing of masses in the crust and do not penetrate into the depths of the mantle.

Crustal allochthones frequently lie on one another, forming tectonic ensembles which are complex in structure. The displacements of masses of deep crystalline rocks of the granite-metamorphic layer are most significant in extent; as a result of movement they are on top, covering considerably younger formations of the sedimentary cover. Such covers have been found in the Carpathians, Dinaric Alps, Eastern Alps, Himalayas and other regions.

Deep mantle allochthones consist of ophiolitic series. As already noted, ophiolites are complexes of rocks of the earth's oceanic crust, also including ultrabasic rocks of the mantle. Such a type of allochthone (thrusts, major covers) have been well studied on the Koryakskoye Plateau, Kamchatka, Sakhalin, in Japan, in the Philippines, in New Caledonia, on New Guinea and Cuba, and in

many other regions bordering the oceans where island arcs occur. A study of "drawn out" and upward-displaced plates of the oceanic crust and also the results of investigation of ophiolites within the continents (Urals, Caucasus, Tien Shan, Pamir, etc.) provides convincing evidence that in this case as well (under upper mantle conditions) deep movements (ruptures) occurred at different levels.

Recently proof has been obtained of ruptures of rock masses in the discontinuity zone between the earth's crust and mantle, called the Mohorovicic discontinuity. There are no deep rocks of the upper mantle in these disrupted and displaced complexes in this zone. It therefore becomes clear that the Moho is an important zone of structural stratification of the lithosphere, a zone of structural disharmony between the crust and mantle. A spatial redistribution of a great quantity of lithospheric material occurs in this zone. A very characteristic example of such a redistribution is the western margin of the North American continent where the continental crust covers the oceanic crust and slips along it, burying under itself the oceanic strata, including very young strata. In other words, in the Moho zone the continent slips along its basement.

Whereas processes of such a character are easily discerned along the periphery of the oceans, in their internal regions, under a great thickness of water, it is considerably more difficult to recognize indicators of the movement of masses. However, without question, movement also occurs here. In a rather great number of regions of the ocean floor dredges have raised fragmented rocks of the oceanic crust which are highly modified by dynamometamorphism*. During abyssal drilling from the "Glomar Challenger" layers of fragmented rocks were also discovered in several boreholes. Their origin can be easily explained if they are considered to be the result of fragmentation occurring during the horizontal movement of plates. The crowding together of plates can also explain many oceanic structural forms whose crustal thickness is 3-5 times greater than the usual thickness. Moreover, the origin of such gigantic tectonic-magmatic forms of the ocean floor as mid-oceanic ridges can scarcely be explained without taking into account the horizontal tectonic crowding together of mafic and ultramafic rock masses.

Thus, we wish to bring attention to the fact that not only the lithosphere itself moves and is dislocated disharmoniously relative to the asthenosphere, but also intralithospheric crustal and mantle plates of different magnitude are crumpled disharmoniously, finally forming an extremely complex internal tectonic structure of the lithosphere as a whole. Over the course of the phases of major tectonic movements, simultaneously affecting the entire lithosphere (not the crust alone) and in area affecting very great regions of the earth there is a differential movement of plates of different magnitude. This movement causes the crowding together of the earth's crust in one place and its dilatation in another. Major new inhomogeneities are formed in this case in the lithosphere, determining the specifics of its structure, structural evolution and magmatic processes.

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* Dynamometamorphism is the structural and to a lesser degree the mineralogical transformation of rocks under the influence of tectonic forces in the fold-formation process.

Recently studies have appeared in which an attempt has been made to demonstrate that the plates made up of heavy mantle rocks move several times more rapidly that the lighter sialic crustal plates, although both move in one and the same direction. This should inevitably lead to a rupturing and disharmonious crumpling of such different plates.

The described concept of a global structural stratification of the lithosphere is based on a recognition of the greater role of different types of physicochemical inhomogeneities in the lithosphere, which also determine the course of geological processes in it and its internal structure. Great attention must be given to study of such an inhomogeneity as the Mohorovicic discontinuity, within which there is a considerable spatial redistribution of material in the lithosphere. This can explain both the drift of the continents and many phenomena of magmatic activity and metallogeny, and in particular, the unusual diversity of magmatic and metallogenic phenomena on the continents, which cannot be done if it is assumed that there are unified enormous lithospheric plates.

A model of tectonic stratification is being developed at the Geological Institute, USSR Academy of Sciences. From our point of view, precisely it is a development of the classical Wegener mobilism in modern geology.

Formation of Oceans

Both the continental and oceanic crusts have been subjected to breakdown. At the surface a variety of structural forms can arise, most frequently linear. During recent years it has been rifts that have drawn the greatest interest among such forms. This term is used to designate narrow and extensive depressions forming as a result of dilatation of the earth's crust and accordingly having increased permeability for magmatic masses. Rifts extend very extensively both on the continents and in the oceans. They are attracting attention because the divergence of the walls of such depressions in the direction away from the axis can lead to the appearance of deep fissures in the continental crust up to the formation, in extremal cases, of oceanic spaces.

Lake Baykal is a classic rift structure in the USSR. The "Paysis" underwater vehicle with three aquanauts aboard submerged to its bottom in 1978 to a depth of 1410 m*. This expedition of the Institute of Oceanology imeni P. P. Shirshov, USSR Academy of Sciences, collected new data giving evidence of the rift nature of the lake. It is exceedingly important that the thickness of the crust beneath Baykal, according to data from deep seismic sounding, is 34-35 km, whereas under the ranges surrounding the lake it is 41-46 km. An increased heat flow emanating from the deep layers was registered there. We note that the Baykal rift is part of the Baykal rift zone, consisting of series of rift valleys and extending for 2500 km.

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* Monin, A. S. and Mirlin, Ye. G., "Study of the Floor of Baykal Using Underwater Vehicles," PRIRODA (Nature), No 10, p 58, 1978.

The rift-formation process has progressed further in the Red Sea. Early in 1980 a Soviet expedition also worked here. It made detailed investigations at a depth of about 2 km using the same "Paysis" and unmanned vehicles*. In the axial zone of the Red Sea, whose width is several tens of kilometers, the earth's crust has an oceanic structure, whereas to the west and east of it there are the continental masses of Africa and Arabia. It has been calculated that over the last 3 million years the walls of the Red Sea rift have moved apart at a rate of 1.6 cm per year. Hot brines emerge at the sea floor, giving rise to metal-bearing sediments. In the cross section the sea floor is represented by two systems of steps dropping off to the axial zone. From the bottom scarps the expedition collected a great collection of basaltic rocks characteristic of the oceans.

The Red Sea rift is part of the East African rift zone, complex in structure and enormous in extent. It is easy to visualize that with an increase in the rate of separation and in the course of a more prolonged time the narrow zone of the oceanic crust can be transformed into a broad zone and an extensive oceanic region develops. Such a mechanism is exceedingly suitable for explaining the origin of the Atlantic Ocean.

This ocean consists of two parts: northern and southern. The South Atlantic was formed as a result of the breaking apart of the ancient continent of Gondwana and the moving apart of such major parts of it as Africa and South America. There are many geological and paleontological proofs of the former unity of Africa and South America. The breakdown of the ancient continent began 135 million years ago. Over the course of the first 35 million years it occurred relatively slowly. But then the rate of formation of the ocean increased and soon the outlines of South America became close to what they are today. The North Atlantic was formed somewhat later and its arctic part considerably later -- approximately 65 million years ago. The geological situation here was substantially different. Within the limits of the present-day ocean at an earlier time there were folded structures which were situated close to one another; the Appalachians and Scandinavian mountains with respect to origin and structure are extremely similar to one another. In turn, these structures developed at the site of the more ancient Atlantic -- the Pra-Atlantic -- existing 450 million years ago and even in more ancient times. Such a difference in history was reflected in the features of structure of the South and North Atlantic, including in a different chemical composition of the basalts, which, in all probability, is evidence of major mineralogical inhomogeneities in the mantle.

The tearing apart of Australia and Antarctica, as well as Africa and Madagascar, has been found to be as convincing as in the case of Africa and South America. It can therefore be assumed that a number of regions in the Indian Ocean were formed the same as the South Atlantic -- as a result of the spreading-apart of the blocks of the ancient continents. The western, European part of the Arctic Ocean also has a clearly validated "broken-apart" nature.

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* Monin, A. S. and Yastrebov, V. S., "Expedition to the Red Sea," PRIRODA (Nature), No 9, p 25, 1980.

However, the Eastern Arctic was formed in a different way. The Beaufort depression and the chain of basins extending along the eastern margin of the Lomonosov Ridge have a suboceanic structure of earth's crust and developed as a result of complex processes of movement of deep masses against a background of dilatation of the crust and its warping during the course of the Late Jurassic -Late Cretaceous. Such a conclusion follows from a tectonic analysis of the oceanic region, the shelf and the continental regions of the Arctic and Subarctic.

The rupturing of the continuity of the earth's crust, its destruction and the impairment of the relationship of layers existing in it in the direction of degradation of the crust will be called tectonic destruction. This is a very widespread phenomenon on the earth, accompanying the development of the continents and oceans. Finally, the replacement of one structural plan in one region or another by a different structural plan is caused by the appearance of tectonic destruction of the crust. That is why the investigation of this very important complex of processes is now attracting the attention of many Soviet geologists, who have already discovered a great number of ancient destructive tectonic formations.

However, despite the fact that both destruction and accretion are extremely macroscale geological phenomena, it has not been possible to discover a full explanation for them. It is probable that these processes were caused by the complex interaction of both cosmic and intraterrestrial forces.

For the time being it is simplest to explain the origin of zones of accretion and destruction on the assumption that the crust and mantle have a multilayered structure and the flow of material in each of the layers transpires at different rates -- differentially. It is understandable that with the differential movement of plates any change in the rate of movement of one of them causes a change in the construction of all the plates in this region, the simultaneous formation of zones of crowding together and destruction, and also zones of varied magmatism.

We note that all the modern and ancient zones of accretion and destruction on the earth and have an asymmetric structure in cross section: all the zones of folding on the continent are asymmetric; the island arcs of the "active" margins and the zones of destruction on the "passive" margins of the continents are asymmetric; the zones of continental and even mountain ridges of the oceans are asymmetric, as is expressed, in particular, in a different steepness and length of the slopes of the oceanic ridges and rift zones. These features of the structure of the earth's crust have not yet been explained, but they scarcely can be understood if the collision of differentially moving plates is not taken into account.

A number of researchers give great importance to the earth's asymmetry as a whole. In one half of the earth -- the Indian Ocean-Atlantic Ocean part -- the continents are concentrated, whereas in the other half, the Pacific Ocean part, only the margins of the continents and the largest oceanic region of the earth. V. I. Vernadskiy, almost 60 years ago, was the first to draw attention

to such asymmetry. Later the asymmetry idea was developed by N. S. Shatskiy, N. P. Kheraskov, A. L. Yanshin and other researchers.

Structural asymmetry has now been established on other planets of the earth group (Mars, Mercury) and on the moon. Developing the idea further, one of the authors of this article came to the conclusion that since the planets of the earth group, and also the earth's satellite, the moon, are in different stages of evolution from the earliest (moon) to the most mature (earth) and on virtually all there are indications of asymmetry, structural asymmetry is a primary property of the planets and reflects the primary global inhomogeneity of their structure.* Thus the features of primary inhomogeneity have not been erased on the earth during its enormously long geological history, reckoned at 4.55 billion years.

It is very important that recently geochemists have begun to speak out on the primary (accretional) inhomogeneity of the planets**. The basis for this has been data on isotopic anomalies in meteorite matter. The conclusion can be drawn on the basis of these data that the primordial solar nebula had great inhomogeneities of the chemical and isotopic composition of the elements and that these inhomogeneities were inherited during the condensation of the planets. However, the appearance of inhomogeneities in the solar corona is related to an incomplete mixing of the products of supernova explosions occurring 10^6-10^8 years prior to condensation.

Thus, tectonic, comparative planetological and geochemical data excellently agree with one another. It cannot be doubted that there are great possibilities for research.

In its ancient geological history the Pacific Ocean is shrouded in mystery. Its structural evolution is more or less clear only during the last 100-150 million years. It was precisely during this time that the principal features of the modern structural plan of the ocean were formed; it is complex and diversified in different regions. Here there are also gigantic fault zones, extending for thousands of kilometers, along which there were great shearing movements, and enormous linear volcanotectonic ridges, as well as rises of irregular configurations with a thickened crust, broken into blocks, together with basins of different size, beneath which the crust is thinnest. But the largest element of the oceanic structures is the enormous East Pacific Ocean Rise, tectonically the most mobile and youngest zone of the oceanic crust. It is very important that these oceanic structures did not develop simultaneously. Accordingly, the oceanic crust is not solidified, but subject to tectonic transformation. New structures are formed against the background of old structures. So it unquestionably was at an earlier time in the earth's existence.

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* Pushcharovskiy, Yu. M., Kozlov, V. V. and Sulidi-Kondrat'yev, Ye. D., "Tectonic Asymmetry of the Earth and Other Planets," PRIRODA (Nature), No 3, p 32, 1978.

** Barsukov, V. L., "Early History of the Planet Earth," PRIRODA, No 6, p 30, 1981.

It is interesting that the stages in intensified tectonic activity in the Pacific and other oceans frequently coincide in time with the phases of tectonic activity within the limits of the continental margins.

But if it is assumed that the Pacific Ocean and its margins are tectonically developed in interrelationship to one another, very important conclusions will follow from this concerning the tectonic evolution of the Pacific Ocean segment of the earth in general. This opens up a new and very important direction in work: correlation of geological events in the oceanic region and on its periphery.

In concluding the article we note that it has been recently suggested on the pages of some journals that in the not distant future the problems of tectogenesis on the earth, including in the oceans, will not be solved by geologists but by physicists, chemists and mathematicians. Geologists, in the solution of global problems, have always used data from these sciences, but it can be seen from all preceding experience that it is precisely geologists, who as in the past, must solve the fundamental problems of structure, evolution and geodynamics of the earth, and to be sure, the origin of its most important structural features.

5303
CSO: 1865/105

BRIEFS

ATLANTIC EXPEDITION COMPLETED--Leningrad. The research ship "Professor Vize" has returned to its native shores from the North Atlantic. The ship belongs to the Arctic and Antarctic Scientific Research Institute. The participants on the voyage, headed by A. Nagurnyy, expedition chief, and captain Yu. Burmistrov, carried out multisided investigations of a number of regions in the North Sea, Norwegian Sea and Greenland Sea, as well as the Denmark Strait between Greenland and Iceland. This most recent distant voyage coincided with a noteworthy event in the biography of this ship. Fifteen years have passed since the USSR national flag has been raised on the motor vessel, constructed for studying the large-scale interaction between the ocean and the atmosphere, conditions for weather formation, hydrological and ice characteristics. There have been 38 voyages, including 10 to Antarctica. It has voyaged more than 722 thousand miles. A total of 82 automatic buoy stations have been set out and more than 90 meteorological rockets and 5300 radiosondes have been launched. Our ship has participated in many national and international scientific programs carried out in different regions of the world ocean. [By V. Khokhlov, first assistant captain] [Text] Moscow VODNYY TRANSPORT in Russian 7 Jan 82 p 4] 5303

CSO: 1865/93

UDC 532.59

AMPLITUDE CHARACTERISTICS OF THREE-DIMENSIONAL INTERNAL WAVES IN OCEAN CURRENTS

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I TEKHNICHESKIYE NAUKI in Russian No 12, Dec 81 (manuscript received 24 Apr 81) pp 55-59

SUVOROV, A. M., TANANAYEV, A. N. and CHERKESOV, L. V., associate member, UkSSR Academy of Sciences, Marine Hydrophysics Institute, UkSSR Academy of Sciences; Sevastopol' Instrument Making Institute

[Abstract] A general formulation is given for the problem of unsteady three-dimensional internal wave motion in the sea approximated by a liquid with N layers of different densities and current velocities. Specific numerical calculations are given for the amplitude characteristics of internal waves. The equations, boundary conditions and initial conditions in the linear theory are written in a coordinate system fixed to the moving region of atmospheric pressure perturbations using Fourier and Laplace transforms, giving an exact solution of the problem within the framework of the linear theory that describes displacement of the boundary of layers of the liquid from the undisturbed state. This solution is valid even when the flow of stratified liquid is unstable with respect to perturbations caused by an external source. However, in this case the solution describes wave motion only during the initial time segment when the wave amplitude is small enough that nonlinear effects can be disregarded. At higher amplitudes, equations and boundary conditions must account for nonlinear terms. An investigation is made of the influence that shear flow has on wave behavior. Figures 2, references: 3 Russian.
[97-6610]

UDC 551.463.6

QUESTIONS CONCERNING STRATIFICATION OF VERTICAL TEMPERATURE GRADIENTS IN SEA ENVIRONMENT

Kiev VISNYK AKADEMII NAUK UKRAYINS'KOYI RSR in Ukrainian No 2, Feb 82 pp 20-24

PEROV, M. H., candidate of technical sciences, and VOSTROKNUTOV, O. O.

[Abstract] Studies of sea environment require determination of vertical temperature gradients of the active surface layers of seas and oceans. During the vertical sounding of sea environment the temperature sensors are affected by

the stratified structure of sea water with a variety of manifestations of temperature heterogeneity, which in general can be represented in the form of an equivalent sinusoidal effect. Several types of vertical temperature distributions, temperature gradient and conductivity have been reported as a function of depth. The curves were determined in the Black Sea. These typical cases of vertical stratification of the temperature gradient have been analyzed mathematically using three specific cases: equivalent sinusoidal distribution of the temperature gradient, jumps of temperature gradient from layer to layer and a case where at a steady temperature, equivalent temperature layers with the gradient $G_\theta = 0$ are separated by thin layers with gradients $G_\theta \neq 0$. It was shown that determination of the vertical temperature gradient is within the limits of the sounding speed, which does not exceed 60 cm/sec at $T_D \geq 0.05$ sec. At this sounding rate tossing of the vessel complicates determination of the image of vertical distribution of hydrophysical layers. References: 2 Russian. [108-7813]

TERRESTRIAL GEOPHYSICS

SOVIET UNION PROGRAM FOR STUDY OF EARTH'S DEEP LAYERS

Moscow PRIRODA in Russian No 1, Jan 82 pp 3-13

[Article by V. V. Belousov]

[Text] Biographical data on author. Vladimir Vladimirovich Belousov, corresponding member, USSR Academy of Sciences, section head at the Institute of Physics of the Earth, USSR Academy of Sciences, chairman, Interdepartmental Geophysical Committee, USSR Academy of Sciences, chairman, Scientific Council on Multisided Investigations of the Earth's Crust and Upper Mantle, USSR Academy of Sciences, deputy chairman, Scientific Council on Study of the Earth's Deep Layers and Superdeep Drilling, USSR State Committee on Science and Technology. Specialist in the field of the earth's tectonics, author of more than 200 scientific studies, including the monographs: OSNOVNYYE VOPROSY GEOTEKTONIKI (Fundamental Problems in Geotectonics), Moscow, Gosgeoltekhizdat, 1962; ZEMNAYA KORA I VERKHNYAYA MANTIYA MATERIKOV (Earth's Crust and Upper Mantle of the Continents), Moscow, Nauka, 1966; ZEMNAYA KORA I VERKHNYAYA MANTIYA OKEANOV (Earth's Crust and Upper Mantle of the Oceans), Moscow, Nauka, 1968; ENDOGENNYYE REZHIMY MATERIKOV (Endogenous Regimes of the Continents), Moscow, Nedra, 1978.

The "Fundamental Directions in Economic and Social Development of the USSR During 1981-1985 and for the Period Until 1990," adopted by the 26th CPSU Congress, provide for a considerable expansion of the mineral-raw material base of the USSR. This task requires an intensification of both regional geological and geophysical investigations and also investigations of a fundamental character in the full range of the earth sciences. This objective is also pursued by the program for extensive study of the deep layers of our country by geological, geophysical and geochemical methods, accompanied by theoretical studies, which in more than one five-year plan has been declared to be one of the most important national economic programs by the USSR State Committee on Science and Technology.

The object of this research program is the earth's crust and the earth's upper mantle, which together are usually called the tectonosphere. Concentrated in the tectonosphere is that energy which causes movement of the earth's crust. Melts are formed in the crust which rise to the surface and cause volcanic eruptions.

Structure of the Tectonosphere and Methods for Its Investigation

The tectonosphere has a complex structure. At the top lies the earth's crust, almost entirely solid, on the continents having a thickness from 300 to 70 km. It consists of different rocks -- sedimentary, magmatic and metamorphic. At the top there is usually a layer of sedimentary rocks which locally can attain a thickness of 20 km. In the underlying consolidated, that is, denser crust, at the top there is a predominance of magmatic and metamorphic rocks, relatively rich in silicon oxide (acidic rocks), and at the bottom there are rocks which are poorer in silicon oxide and denser (basic rocks). Seismic investigations show that with increasing depth the velocity of the longitudinal seismic waves in the crust increases from very low in the sedimentary layer to 7 km/sec at the base of the crust. Traditionally the upper part of the consolidated crust is called the "granite" layer and the lower part is called the "basalt" layer, although it is now clear that at least with respect to the lower layer these names do not entirely correspond to the real composition of the rocks.

The crust is separated from the mantle underlying it, called the upper mantle, by a rather distinct discontinuity at which seismic velocities increase with a jump (usually up to 8 km/sec or about that). The uppermost part of the upper mantle to a depth of 100-150 km is almost completely solid. Accordingly, in many cases it is convenient that the crust and this solid part of the upper mantle be considered together. Then they are called the "lithosphere." In the lithosphere the velocity of seismic waves also continues to increase with depth below the crust (to 9 km/sec). But beneath the lithosphere there is a layer locally having a thickness of 10-20 km and locally attaining 100-150 km in which the velocity of seismic waves is somewhat reduced (by 0.3-0.4 km/sec in comparison with the layers lying above it). At greater depths the velocity again increases.

A decrease in the velocity of seismic waves is evidence of the special physical properties of the layer lying beneath the lithosphere, the asthenosphere. At present there is a unanimous opinion that these properties of asthenospheric matter are caused by the partial melting of its matter. The upper mantle consists predominantly of peridotite, an ultrabasic rock consisting of the minerals olivine, garnet and pyroxene. When the temperature attains 1400-1500°C the olivine remains hard but the garnets and pyroxenes melt. This gives rise to a melt having the composition of basalt. Precisely such a partial melting occurs also in the asthenosphere. Depending on the temperature and pressure the degree of melting can be different. In this connection there is a different influence of melting on the velocity of seismic waves. On the average the volume of the melt can be considered equal to 15% of the total volume of the asthenosphere, but locally it possibly attains 25%. Partial melting leads to an increase in volume, a decrease in the mean density of matter and a decrease in its viscosity. The latter circumstance makes it possible to ascribe to the asthenosphere an important role in tectonic movements of the earth's crust and the entire lithosphere: on the one hand, currents in the asthenosphere can deform the lithosphere, and on the other hand, the lithosphere can creep

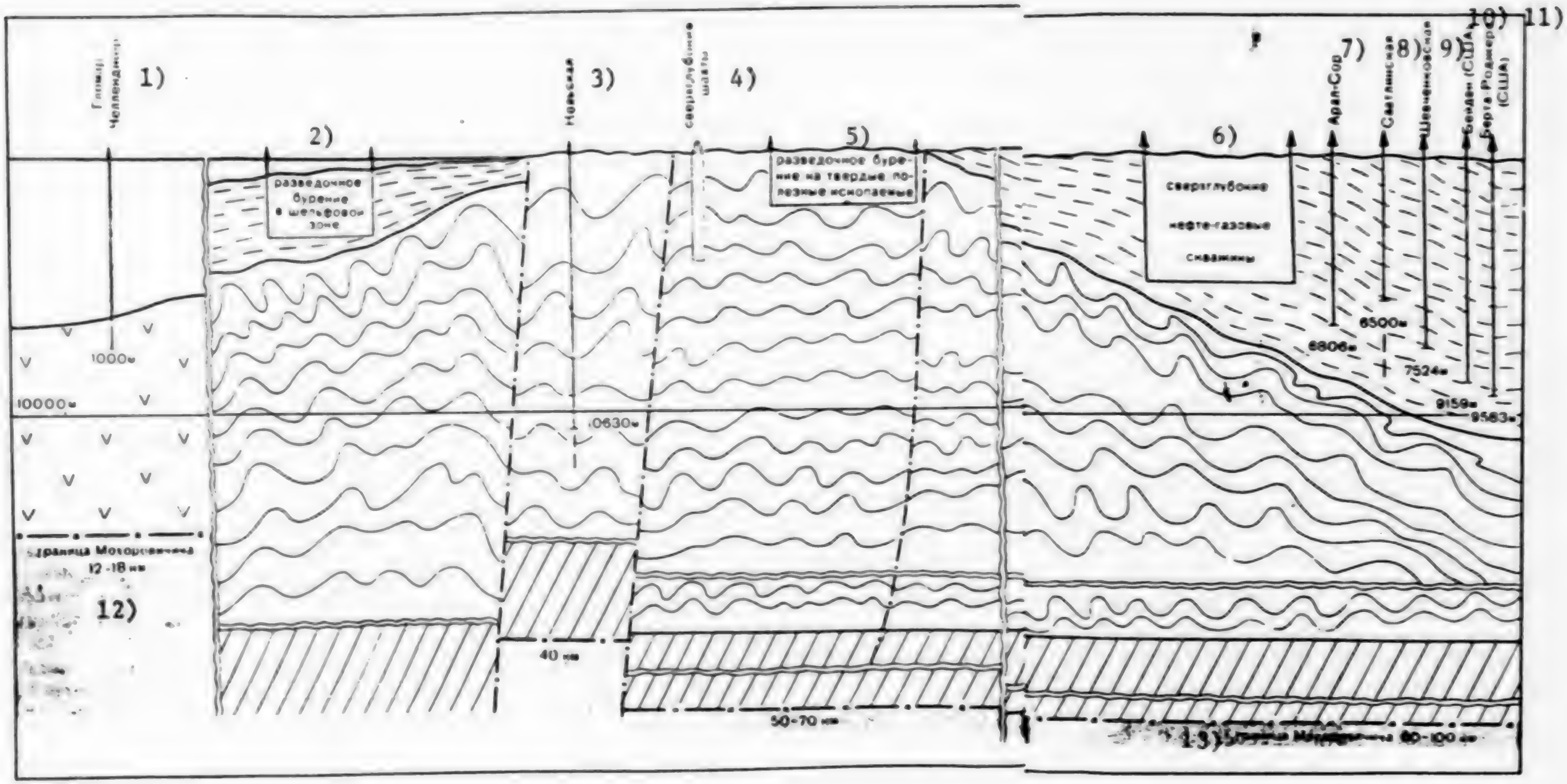


Diagram of study of earth's crust
by geophysical methods.

Annotations on next page.

Phanerozoic sedimentary rocks

Oceanic basalts

Dislocated rocks of "granite" layer

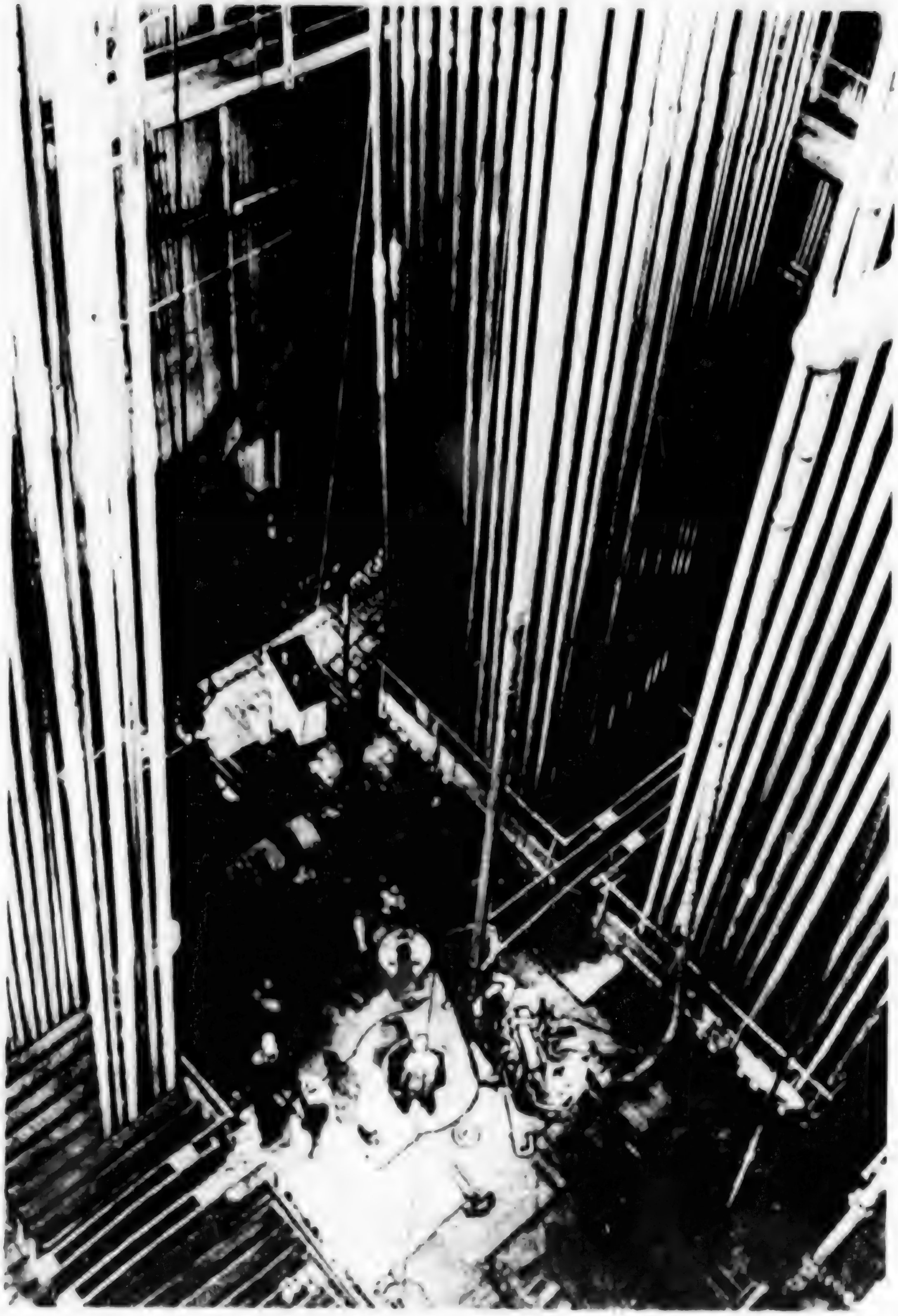
Rocks of "basalt" layer

Mantle rocks

KEY TO FIGURE:

1) Glomar Challenger
2) Exploratory drilling in shelf zone
3) Kola
4) Superdeep shafts
5) Exploratory drilling for solid minerals
6) Superdeep gas-petroleum boreholes
7) Aral-Sor
8) Saatlinskaya
9) Shevchenkovskaya
10) Byden (United States)
11) Bert Rodgers (United States)
12) Mohorovicic discontinuity
13) Mohorovicic discontinuity

Rock samples raised from depth of 10 547 m. Photograph by S. A. Maysterman. [TASS photo archives].



"Uralmash-15000" drill rig at the Kola superdeep borehole. Photograph by S. A. Maysterman [TASS photo archives].

along the surface of the asthenosphere, encountering little resistance. The lower boundary of the tectonosphere is at a depth of about a thousand kilometers, but its most active and interesting part is bounded by the asthenosphere.

Complex physical and physicochemical processes transpire in the tectonosphere. These must be studied in order to clarify the origin and patterns of development of different geological structures. Since observations of modern manifestations of endogenous processes, such as earthquakes or volcanic eruptions, are entirely inadequate for forming any idea concerning the development of these processes over the course of hundreds of millions and billions of years of geological history, the researcher must reconstruct the picture primarily on the basis of those traces which these processes have left in different features of structure of the crust and upper mantle. Accordingly, this structure must be studied to the fullest possible degree.

Different methods can be used here. The geologist studies the structure of the surface and then, extrapolating these data, judges the structure of the several upper kilometers of the earth's crust. The direct methods include drilling, but usually drilling can extend to depths no greater than 5 km. Only very infrequently have boreholes penetrated to depths of 7-9 km. Then comes the extensive field of use of use of geophysical methods. Their role is exceptionally important in the earth sciences. However, being indirect, these methods reveal only the physical properties of the rocks (elasticity, density, conductivity, magnetization) and they do not provide a direct answer to the question of their composition and age because rocks of different composition can have similar properties. All this in a number of cases makes difficult a geological interpretation of the geophysical data.

This difficulty has become particularly important since the time that mineral deposits lying relatively close to the surface have become exhausted and the need has arisen for a detailed study of the deep layers of the crust.

Soviet geologists have striven to overcome precisely this difficulty. Even prior to the Great Fatherland War 1941-1945 they advanced the idea of deep drilling for scientific rather than reconnaissance purposes. It was proposed that by means of drilling it is possible to create a network of well-studied reference sections of the crust to a depth of 4-5 km. It was planned that these sections also be investigated by geophysical methods, which would make it possible to extrapolate the results of drilling to extensive areas.

The first experience in such joint use of geophysical and drilling data gave rise to a reference drilling program. It was carried out primarily over the course of the first post-war decade. At the same time this was the first attempt at use of drilling over an extensive area for purely research purposes. Many tens of reference boreholes were drilled in the East European platform and in Western Siberia. Due to these boreholes we have sections of sedimentary strata in both these regions. Locally reference boreholes have penetrated the entire sedimentary cover as far as the basement. Geophysical profiles and surveying afforded the possibility of extrapolating data from boreholes over extensive areas. Reference drilling in many respects has favored success in a search for petroleum and gas deposits in the Volga-Ural region and in some other regions of the Russian platform and in Western Siberia.

Kola Borehole and General Superdeep Drilling Program

A new stage in study of the deep layers of the Soviet Union began in the late 1950's, when a superdeep drilling project began to be discussed in the scientific and production circles of the USSR. By that time the development of drilling technology made it possible to assume that in the years immediately ahead it would be possible to plan boreholes with a depth as great as 12-15 km. Thus the Soviet program for the drilling of superdeep boreholes in the continental crust was born.

By this time there were already several boreholes with a depth of 7-9 km in the USSR and the United States. They were drilled for the purpose of seeking petroleum and fuel gas. They were drilled in sedimentary basins and as a rule penetrated the same sedimentary layers as emerge at the surface at the edges of the basin. In this connection, while solving purely reconnaissance problems, these boreholes yielded little which was new for an understanding of the structure and composition of deep regions of the crust.

In the early 1960's different possible sites for drilling the first superdeep borehole were discussed. In these places it would be possible to attain deep layers of the earth's crust whose composition still was completely unknown. Finally, the Kola Peninsula, its northwestern part, was selected. The following considerations were taken into account in this decision.

Precambrian rocks outcrop at the surface on the Kola Peninsula, a part of the ancient Baltic crystalline shield. At the site selected for the borehole there were Proterozoic rocks whose age was greater than 2 billion years. Judging from the geophysical data, not far beneath them at a depth of 3-4 km, one should find the most ancient of the rocks known in the crust -- Archean (age more than 3 billion years). Under these conditions the superdeep borehole had chances to penetrate into those deep layers which not only had never been seen at the surface, but also which had never been reached by boreholes.

This assumption was confirmed by the fact that according to geophysical data in the region of drilling the boundary between the "granite" and "basalt" layers of the crust is situated at a depth of only seven kilometers. Thus, it was assumed that a borehole with a depth of 10 km would intersect the entire "granite" layer and would enter the "basalt" layer, which nowhere approaches close to the surface and whose nature is still unclear. This borehole thus promised to penetrate the deep layers of the earth's crust and supply us with information on their composition. The choice of a site for the first superdeep borehole was also justified by the practical interests related to the search for minerals.

Drilling of this unique borehole began in 1970. It was initially intended to reach a depth as great as 10 km. This drilling constituted a highly complex technical problem, especially if it is taken into account that a maximum core yield had to be ensured and that a complex of diversified geophysical measurements had to be carried out regularly in the shaft of an uncased borehole. The difficulties were increased still more due to the severe climatic conditions of the Kola Peninsula. This makes it all the more surprising that by late 1980 the borehole without a single accident had attained a depth of 10 600 m with an uncased shaft

and now the immediate goal is a depth of 13 km. This is an enormous achievement of Soviet drilling technology.

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In the tundra there is a structure similar to a factory. In addition to the drill rig, with a height greater than 60 m, here there is a building where the drilling equipment, repair-mechanical workshop, automatic drilling control system, television panel and laboratory for the primary documentation of the core and storage for core samples are situated. Living quarters have been constructed.

With respect to the scientific results, in this respect as well the success of the first superdeep borehole exceeded expectations. This success was a result of the efforts of many scientific and production institutes of the Geology Ministry and USSR Academy of Sciences, which jointly conducted observations and processed the collected data.

Despite geophysical predictions, the borehole passed through Proterozoic rocks not to 3-4 km, but to 7 km, that is, to the depth where the transition from the "granite" layer to the "basalt" layer was postulated. The Proterozoic stratum was represented by an alternation of volcanic (diabases, andesites, trachyandesites) and sedimentary (sandstones, argillites) rocks. They all have been metamorphosed; with depth the degree of metamorphism increases. The maximum temperature of metamorphism is about 600°C, pressure is 6-7 kbar. In the epoch of metamorphism the geothermal gradient (rate of temperature increase with depth) attained 100°C/km, which is three times greater than the normal gradient and 4-10 times greater than the gradient now observed in the borehole.

But it was something else which caused the greatest surprise to the researchers. Instead of penetrating into the "basalt" layer, at a depth of about 7 km the borehole penetrated into a stratum of plagioclastic gneisses, granite gneisses and amphibolites of Archean age. No layer consisting of basalts formed any continuous mass of basic rocks at this depth! On the whole, these were rocks of average composition with an average silicon oxide content. It can only be noted that with depth there is an increase in the number of intercalations of amphibolites, that is, rocks of a basic composition: at a depth of 7 km they constituted about 10% and at a depth of 10 km -- about 30%. These changes in the relative role of amphibolites were reflected in a change in the mean elastic properties of rocks. The velocity of seismic waves in Archean rocks increases from 6.1 km/sec at the top of the Archean layer to 6.5-6.6 km/sec at a depth of 10 000 m. Evidently, precisely this increase in velocity over the course of several kilometers also gave seismologists the impression that there is a sharp discontinuity between the "granite" and "basalt" layers.

The bedding of the rocks in the deep layers was equally unexpected. Profiles constructed by the deep seismic sounding method usually show that the earth's crust in its lower part is divided into a number of almost horizontal layers. At the surface, however, in the place where the borehole is situated, layers of the Middle Proterozoic lie at angles from 45 to 60°. The deep seismic sounding profiles, run before the borehole was drilled, indicated that such a slope of the seismic discontinuities persists to a depth of about 4 km. Deeper all the discontinuities become almost horizontal. In actuality, however, as indicated by measurements in the borehole shaft, all the rocks, right up to the face, that is, to a depth of 10 600 m,

slope at the same angle as at the surface (from 45 to 60°). The question arises as to what the seismic discontinuities reflect in this case if they do not coincide with the boundaries of geological bodies? Are they the result of different degrees of metamorphism and increased density of rocks with depth? Or possibly are they a result of the formation of gently sloping fractures and zones of cataclasm, which, incidentally, were locally intersected by the borehole? In any case, serious reasons arose to doubt that the deep seismic profiles register the forms of bedding of rocks.

The borehole made possible a more precise determination of the geothermal gradient. The present-day gradient on the Kola Peninsula varies from 10 to 25°C/km: at a depth of 7 km the temperature is 120°C, at a depth of 8 km it increases only 10°, but at a depth of 10 km increases to 180°.

Many other highly interesting observations have been made in the Kola superdeep borehole; at present the results of these studies are being processed by specialists.

The borehole is continuing to be deepened and without question it will provide us much new information concerning the deep layers of the earth's crust. On the Kola Peninsula the thickness of the crust is about 40 km and technically, to be sure, it is impossible to reach its bottom. But if the borehole attains a depth of 15 km it will penetrate almost half the thickness of the ancient continental crust, which will make it possible to replace many of our guesses concerning the composition and structure of the latter by solid knowledge.

The success of the Kola borehole had the result that superdeep drilling came to be regarded as a method for studying the deep layers of the earth's crust for scientific and practical purposes, meriting development and broader application. Accordingly, a long-range program was developed for such drilling in different regions of our country.

The program indicates about 20 sites for the drilling of superdeep boreholes with a depth of 7-12 km. Half of them are intended for study of the deep structure of regions promising with respect to ore minerals; the other half have as their purpose the study of the petroleum and gas content of deep sedimentary layers. Ten boreholes were designated as primary; it is planned that they be drilled prior to 1990.

The second superdeep hole which is being drilled is the Saatlinskaya borehole. This borehole was drilled in the young sedimentary strata of the Kura depression in Azerbaijan in 1977. Since that time it has entered Mesozoic volcanic rocks and by late 1980 had reached a depth of 6680 m. The borehole should intersect the entire thickness of the Mesozoic rocks and enter into the Paleozoic basement. The practical purpose of the borehole is a study of the prospects for finding petroleum and gas in the Mesozoic and Paleozoic deposits of the Kura depression.

Among the boreholes in the ore regions, those with priority are: Tagil'skaya in the Urals, Krivorozhskaya in the Ukraine, Noril'skaya in the northern part of Siberia, Muruntauskaya in the Uzbek SSR.

Among the boreholes directed to study of the presence of petroleum and gas, those with priority are the following: Tyumenskaya in Western Siberia, Kochmesskaya in the Pechora Lowland, Kenkiyakskaya in the Caspian Lowland, Anastas'yevsko-Troitskaya in the Krasnodarskiy Kray, Vostochno-Poltavskaya in the Ukraine.

Regional multisided geological-geophysical and geochemical investigations of the earth's crust and upper mantle of the territory of the USSR have been carried out and are continuing parallel with this program of deep drilling (and to a considerable degree in connection with it). Substantial successes were attained in this direction in the preceding years.

Geonomy -- the Integrated Science of the Earth

The geological structure of the Soviet Union is exceedingly diversified. Over the extensive area of our country it is possible to encounter all types of structures of the earth's crust characteristic for the continents. The entire territory is cut by deep seismic sounding profiles and covered by geological surveys at various scales; gravimetric, geothermal, geomagnetic and other geophysical maps have been compiled for it; the conductivity of rocks has been determined to great depths along several profiles. Theoretical and experimental studies are being carried out in our country whose purpose is a clarification of the physical and physicochemical properties of rocks and minerals under high-pressure and high-temperature conditions and the recreation of processes transpiring in the depths of the crust and in the upper mantle.

The totality of all these data lies at the basis of our concepts concerning the earth's deep layers. We call these investigations multisided precisely because they combine geological, geophysical and geochemical methods. Such an approach to study of the earth's depths, based on the joint use of the different earth sciences, has been called geonomic by some and it has been suggested that the integrated science of the earth be called geonomy.

Precisely the geonomic approach to study of all the collected data will make it possible to draw conclusions concerning the character of processes transpiring in the earth and determining the development and modern structure of the earth's crust which will be described below.

As is well known, geological processes are divided into exogenous, caused by external forces acting at the earth's surface, and endogenous forces associated with manifestations of the internal forces of the planet. In this case we are only interested in endogenous processes. In turn they are subdivided into tectonic, magmatic and metamorphic. We recall that tectonic processes are manifested in movements and deformations of the earth's crust, its uplifting and subsidence, bending of rock layers into folds and earthquakes; magmatic processes are expressed in the injection of molten masses into the earth's crust and volcanic eruptions; metamorphic processes involve a change in the structure of rocks and their composition under the influence of high temperature and high pressure.

It has been established that all three varieties of endogenous processes develop parallely: in places where tectonic movements are considerable the magmatic processes are usually intensive and diversified and metamorphic transformations of

rocks are also usually observed there. But in those places where the tectonic movements are attenuated there are two other varieties of endogenous processes. In this connection at the surface of the continent it is possible to discriminate mobile, or as they are usually called, excited zones where all endogenous processes are active, and also quiet zones, where these same processes are manifested weakly. It is also possible to speak of excited and quiet endogenous regimes.

A study of geological history reveals that the distribution of regimes at the surface of the continent changed with the course of time: zones or sectors excited in the course of some geological time can later become quiet and vice versa, quiet regions can be involved in greater endogenous activity. Therefore, the distribution of endogenous regimes is variable not only in space but also in time.

The most different regimes, both quiet and having different degrees of excitability, coexist in our day at the surface of Eurasia. The entire range of continental endogenous regimes lies before us. Accordingly, it is possible to compare all these regimes with the deep structure of the crust and upper mantle, which characterizes each of them.

As a result of such a comparison it was found that the endogenous regimes of the continents in the tectonosphere have their "roots," penetrating to depths of several hundreds of kilometers. Under the sectors which over a prolonged period of geological time behave geologically quietly (the vertical movements here occur very slowly, the rising and subsiding regions are separated by low contrasts and folding, magmatism and metamorphism are almost entirely absent), the deep structure is evidence of quiet in the entire tectonosphere. The crust here is thick with a classical increase in seismic velocities with depth, the Moho is clearly expressed and the asthenosphere is thin or totally absent. The ancient platforms are an example, such as the East European platform, most of which extends over the Russian plain from the Baltic Sea to the Urals. The deep layers of the ancient crystalline shields, such as the Baltic shield, are especially quiet. The shields are firmly bonded to the solid blocks of the tectonosphere.

The excited zones are characterized by a different state. Such zones include regions of modern mountain formation, rifts, volcanic regions, active transition regions from the continent to the ocean. Modern mountain formation is observed, for example, in the Tien Shan and in the Pamir. Geodetic and geomorphological investigations indicate that in this high-mountain region the ranges are still growing at a rate of more than 1 cm/year and the depressions separating them are subsiding at the same rate. Rifts are major structures in the earth's crust, with their structure bearing evidence of its strong dilatation. On the land there is an alternation of low ranges with deep depressions between them, bounded by faults and accompanied by volcanic manifestations. An example of a rift area is Lake Baykal and the adjacent regions. A zone of modern volcanism in our territory is Kamchatka with the Kurile Island arc, whereas an active transition zone is the entire system of marginal seas and island arcs between the continent of Eurasia and the Pacific Ocean.

In these regions geophysical methods have been used in revealing evidence of an increased temperature both in the upper mantle and in the crust. The increased heat flow from the earth's deep layers is the most direct evidence of this. It is known that the temperature in the crust increases with depth. This means that the heat

flows from the depths to the surface. The magnitude of this flow can be determined by knowing the geothermal gradient and heat conductivity of rocks. It was found that whereas in quiet regions the heat flow is 1.0-1.2 μcal per 1 cm^2 of surface per second, in the excited regions it is usually twice as great and locally exceeds the quiet flow by a factor of 3-4.

Other indications of the excited regions are expressed in the state of matter in the upper mantle and crust. In the upper mantle of the excited regions there is a decrease in density in comparison with the usual density and also indications of melting. In the seismic profiles the asthenosphere is expressed clearly and is characterized by a great thickness, attaining 100-150 km. In the rift and volcanic regions, and also in active transition zones the semimolten masses with a low density rise from the asthenosphere to the very bottom of the earth's crust and replace the upper layers of the mantle belonging to the lithosphere and usually in a solid state. The thickness of the earth's crust in such regions is frequently reduced in comparison with the normal thickness, as if the crust is partially absorbed by the heated mantle. There are also indications that there is also melting in the crust. A study of the geological history of such regions shows that at times the melting of upper mantle and crustal matter attained a very high degree. Precisely then magmas of different composition melted out and processes of metamorphism of rocks developed.

It is natural to conclude that endogenous regimes reflect the thermal state of the deep layers to a depth of probably several hundreds of kilometers. The degree of "excitability" of different regimes is dependent on the degree of heating of the upper mantle and crust since reduced density in the mantle, melting in the mantle and crust, are associated precisely with strong heating. Still another general conclusion is that the presence at the earth's surface of different endogenous regimes existing side-by-side with one another, and also the evolution of these regimes with time, reflect the spatial and temporal inhomogeneities of the earth's heat field.

This conclusion contains the basis for developing a generalizing theory of structure and development of the earth's tectonosphere. The program for studying the deep layers provides for the development of different aspects of such a theory. A unified theory must explain the origin and mechanism of formation of tectonic structures and magmas of different composition and also the causes and mechanisms of other processes transpiring in the earth's crust, a knowledge of which is necessary for evaluating the prospects of the presence of petroleum and gas and the ore resources of the territory of the Soviet Union and for determining the most promising directions in reconnaissance and exploration work over the course of the next few decades.

The leading organization responsible for the implementation of this entire program is the USSR Geology Ministry. In the development of a number of technical problems and in the implementation of the drilling of boreholes a major role is played by the organizations of the USSR Ministry of the Petroleum and Gas Industry and the institutes of the USSR Academy of Sciences; a number of academies of sciences of union republics and the USSR Ministry of Higher and Intermediate Special Education head and carry out tasks of a research character. About 140 scientific research and production institutes participate in this extensive program.

There is every basis for assuming that the implementation of this program for the multisided study of deep layers in the Soviet Union will lead to a radical improvement in our knowledge concerning the features of structure of the earth's crust, its history and development in all geological regions of our country and thereby will radically favor the broadening and strengthening of the mineral-raw material base of the USSR national economy. At the same time the implementation of this program will in many respects favor the clarification of a whole series of general problems in the structure and development of the earth's tectonosphere.

As we see, this program is directed for the most part to study of the continental crust and continental upper mantle. In this connection it is interesting to note that at the same time that in the Soviet Union such studies have been planned and their implementation has begun, American scientists have proposed a project for drilling many boreholes in the ocean. This project for abyssal drilling will later be transformed into an international program with the participation of several countries, including the USSR. The "Glomar Challenger" drilling ship has been used in drilling more than 500 boreholes in all the oceans. These boreholes for the first time gave information on the composition, age and structure of the sedimentary layer at the bottom of the oceans and on the uppermost horizons of the underlying sediments of the consolidated layer of the oceanic crust, consisting of basalts, once pouring out on the ocean floor. The new data on crustal structure under the oceans were in many respects very unexpected and exerted a strong influence on the modern theoretical representations in the earth sciences. It accordingly turned out that these two projects -- Soviet continental and international oceanic -- supplemented one another.

There is no doubt of the great importance of the oceanic project for science, which dictated the participation of the Soviet Union in this work. But it must be emphasized that while being the most extensive continental country, the Soviet Union is especially interested in clarifying the patterns of structure and development of the continental earth's crust in order to have a thoroughly developed scientific basis for predicting minerals. But even in a more general plan it must be remembered that mankind lives on the continents and the lion's share of the mineral raw material is provided by the continental crust. Although during recent years sea and ocean areas are more and more being drawn into the economic life of man, underwater mineral reserves (primarily petroleum and gas) are nevertheless concentrated for the most part on the shallow-water shelves, that is, in the above-mentioned continental crust inundated by the sea. The more diversified composition and more complex structure of the continental crust in comparison with the oceanic crust makes it possible to assume that in the future the principal sources of mineral raw material will be discovered primarily in a crust of the continental type.

The importance of study of the continental crust is now acknowledged elsewhere than in the USSR. American specialists, after problonged distraction with investigations in the oceans, with continental geology then being considerably neglected, resolutely returned to the latter, declaring 1981-1990 to be the "Decade of Study of the North American Continent." In developing the program for the international project "Lithosphere," which replaced the "Geodynamic Project," it was emphasized, in particular, that the continents merit greater attention than has been devoted to them in the past.

More than anywhere else, in the Soviet Union there has been more consistent implementation of investigations of the structure and patterns of development of the continental crust. This direction is continuing to develop, as its fruits bringing about intensive development of the mineral-raw material base of the USSR.

5303
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NEW METHOD FOR COLLECTING DATA FROM DEEP BOREHOLES

Moscow SOTSIALISTICHESKAYA INDUSTRIYA in Russian 10 Feb 82 p 2

[Article by S. Korepanov, TASS correspondent]

[Text] It is possible to obtain information on the processes transpiring at multi-kilometer depths below the earth and under water by using a special fiber-optical cable created jointly by the scientists and production workers of the Physics Institute and Chemistry Institute, USSR Academy of Sciences, All-Union Scientific Research Institute of Geophysics and Geochemistry, and also the "Sredazkabel'" production combine.

"Usually deep processes are studied from a core brought up from drilled boreholes," states Ye. Dianov, doctor of physical and mathematical sciences, section head at the Physics Institute, USSR Academy of Sciences. "This method is time-consuming, expensive and at the same time it does not by any means supply full information because the rock samples are investigated after removal from deep conditions. Up to the present time it has not been possible to relay more complete information from deep boreholes."

"This problem is solved by a light conductor-fiber of quartz glass with a thickness of a fraction of a millimeter. An optical load-bearing cable -- a light conductor, packed in a protective and strengthening shell carrying the payload, a capsule with geophysical instruments and sensors, from which data are fed upward -- has been developed."

"Such optical cables are promising for geophysical investigations in boreholes for the purpose of prospecting for and exploitation of petroleum, gas and polymetal deposits, as well as other minerals, and also in carrying out deep-water oceanographic investigations."

5303
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DEVELOPMENT OF GEOMORPHOLOGY

Moscow PRAVDA in Russian 26 Jan 82 p 3

[Article by N. Bashenina, doctor of geographic sciences, chief of a laboratory of the MGU (Moscow State University) Geographic Faculty, O. Leont'yev, professor, doctor of geographic sciences, chief of a chair of the MGU Geographic Faculty, and M. Piotrovskiy, senior scientific associate of MGU, candidate of geographic sciences: "Studying the Face of the Earth: Science Horizons: A Portrait of Geomorphology"]

> [Text] Geomorphology... One can assert confidently that this word says little or nothing to the reader at large. It so happened that although it is mentioned from time to time in the general press and over radio and television, its meaning remains vague for many. Meanwhile, this is the science about the relief of the Earth's surface, that natural base on which you and I live. The Earth's surface is the most important element of the planet, which divides its hard mantle--the crust--and the external mobile light mantles--the hydrosphere and atmosphere. An exchange of energy and matter between Earth and space takes place through this surface.

The Earth's relief is formed by the interaction of internal geological factors and external geographic factors with the involvement of the Earth's rotational forces. Geomorphology studies and explains all relief forms and their systems, from continents and ocean troughs to ravines and washouts. Specific relief forms also indicate a specific geologic structure; the features of detrital deposits, soils, vegetation, and the regime of waters; as well as past and future paths of development.

The significance of a knowledge of relief is enormous and diverse for man, for its features largely determine the conditions of life and economic activity. But man himself is transforming the relief more and more: directly, by digging canals, quarrying deep into the ground, and piling up waste heaps and tailings; and indirectly, by affecting natural processes through plowing of the soil, turning rivers into strings of water reservoirs, and so on. These measures are very significant in their effect and often are many times greater in intensity than natural processes. Geomorphology studies all this, taking in a truly enormous and very complex system of phenomena which determine the face of the Earth.

Soviet geomorphologists usually conduct studies in connection with major national economic problems, working together with representatives of other sciences, particularly geological sciences. And so there was the development of a "geological" direction in geomorphology, which established the great significance of active tectonic movements in formation of the contemporary relief. An important morphostructural direction developed on the basis of a contact of geomorphology, geology and geophysics, and it gradually evolved into morphotectonics, which studies the processes and mechanisms of formation of tectonic structures. Geomorphological research of seismic phenomena is developing.

"External" processes also are being studied extensively: traces of the effect of running water, from major rivers to slope runoff after a rain; and the formation of the relief of deserts and permafrost areas. Special attention is given to catastrophic phenomena--collapses, landslides, mudflows and washouts. They are being forecast and defensive measures are being developed.

The marine branch of our science has developed strongly in the postwar years. Study of ocean bed relief has made a very major contribution to ideas of the Earth's structure and has brought scientists face to face with new, funadmental problems. Such was the discovery of a grandiose system of mid-ocean ridges. There are very dynamic changes in the relief of ocean and sea shores, and there are very dynamic movements of sea drift. Therefore the use of achievements of marine geomorphology is acutely necessary during construction in the littoral zone, especially port construction, and in protecting beaches from destruction. The Soviet contribution to marine geomorphology is very great.

Soviet geomorphologists in cooperation with cartographers have taken leading positions in world science in compiling geomorphological maps, which represent the most concentrated and graphic scientific information about relief. There are no general maps at all in other countries similar to the geomorphological maps of the USSR and the world. For example, the world maps for the higher school and seabed maps of great scientific and practical value drawn up at MGU are representative. Soviet works have been the impetus for creation of the Commission for Geomorphological Survey and Mapping--the first and for now the only international center in the field of geomorphology, which brought together scientists of many countries and received UNESCO support. The International Geomorphological Map of Europe and the book "The Relief of Europe" are very important works of the commission which have been prepared for publication.

Geomorphological methods are being used, albeit still insufficiently, in geological surveys and exploration for minerals--petroleum, natural gas, bauxite, construction materials, gold, diamonds, and rare metals.

The cooperation of geomorphology with aerial and space surveys is very productive. This is a unique express method permitting a judgment of the "internal content" of subject territory from the external structure of relief and identification from photographs of the majority of phenomena typical of the Earth's surface.

Systems analysis and computer technology have begun to be applied in geomorphology in recent years. Incidentally, a concept on relief formation was developed

back at the end of the last century which essentially outlines general patterns of self-organizing systems, with remarkable analogies of the stages in development of relief and organisms. This is the teaching on the geographical cycle by the American scientist W. M. Davis, which became one of the foundations of geomorphology and which has been included even in the present-day more complex Soviet concepts.

Extensive and diverse geomorphological studies have been performed and are continuing in the Soviet Union. Over the last decade this field of science has become firmly established in all parts of the country, and especially in Siberia and the Far East, thanks to efforts of the USSR AN [Academy of Sciences] Siberian Department. The multivolume "Istoriya razvitiya rel'yefa Sibiri i Dal'nego Vostoka" [History of Development of the Relief of Siberia and the Far East], awarded the USSR State Prize, was created here with the participation of associates of other organizations. The USSR AN Geomorphological Commission, which sets up conferences on major problems, contributes a great deal to the success of this work. Appropriate chairs of a number of universities prepare specialists. Studies are being performed in academic institutes, the NII [scientific research institutes] of ministries of geology, universities, and certain other higher educational institutions. Geomorphologists also work in many survey and design organizations.

In conformity with resolutions of the 26th CPSU Congress, the protection of nature and the rational use of her resources will be given unremitting attention in the 11th and 12th five-year plans. The importance of Earth sciences, including geomorphology, will begin to rise accordingly. It would appear that it is in this very period that we must take phased steps in creating an integral theory of geomorphology on the basis of global generalizations of vast contemporary material and systems theory. Morphotectonics will be formalized and be developed theoretically and practically. It will be possible to read relief from maps and aerial and space photographs as a reflection of the structures and processes of a number of deep-seated levels as well as planetary and local stresses. This will find wide application in the study of ore deposits, the character of valleys and slopes, and problems of geodynamics and seismicity.

There is every opportunity to increase the contribution of geomorphology in the search for minerals and in the study of shelfs and transition zones between the continents and oceans. Quantitative and prediction studies, including those of catastrophic processes, will have to be developed. Cosmophotogeomorphological maps will become a very important support for the scientifically grounded development of sparsely inhabited territories and for planning oil and natural gas pipelines, roads, and measures for protecting nature. In general, geomorphology has to "work" to an increasing extent as one of the foundations of structural geography--a system of studies for the purpose of rational use and transformation of nature (in the definition of Academician I. P. Gerasimov). It is especially important to develop a "northern variant" of this system, with one of its bases being a comprehensive study of the BAM [Baikal-Amur Railway] zone through the cooperation of geologists, geomorphologists, geographers, permafrost scientists and other specialists.

But this field of knowledge has to obtain full "civil rights" in the system of sciences and the requisite independence and reputation in order to carry out its tasks most effectively. Up until now its no small contribution toward solving major complex scientific and national economic problems has not been singled out, being in the "general pot" of geological-geographical sciences. The problem is that it originated both from geography and from geology, and so it often is placed first with one, then the other "parent" or divided between them, just as it is divided organizationally even today. But geomorphology has its object of study and has become a developed, independent field of knowledge, although it continues to mature and strengthen in close ties with entire groups of geographical and geological disciplines. The fact is that all Earth sciences interact with and enrich each other in one way or another.

It seems to us that it would be advisable to hold a plenary session of the USSR AN Geomorphological Commission in the nearest possible time period with the broad participation of representatives of scientific and practical organizations to discuss the place and role of geomorphology in science and practical work as well as its tasks in the 11th and 12th five-year plans. Resolutions of the plenary session would serve as a stimulus for the more active participation of geomorphological scientists in accomplishing tasks facing the country in the 1980's in light of resolutions of the 26th CPSU Congress.

This does not make it mandatory to form special geomorphological organizations, since this discipline is very effective in the complex of sciences. The most rational organizational form now consists of Earth sciences centers or territorial research centers. This form is dictated by the need for a synthesis of sciences, complex study of territories, and application of sophisticated technology--aerospace, cartographic and computer. In such centers the geomorphological scientists will be able both to accomplish their own tasks better and to cooperate with representatives of other sciences.

Geomorphological subunits in existing organizations must be reinforced, and their ties with practical work strengthened. There must be propaganda of geomorphology in the press and on television. All this will help it increase its contribution to science and practical work.

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BRIEFS

NEW GEOPHYSICAL METHOD--Frunze, 11 Jan (TASS)--One of the promising methods for predicting earthquakes, based on deep electromagnetic sounding, has been tested in seismically active regions of Kirghizia by specialists of the Kirghiz Scientific Research Electric Power Section of the USSR Ministry of Power and Electrification. "It is known that a change in seismic conditions results in variations in conductivity in the earth's depths," states B. Botbayev, deputy section head. "A study of these changes makes it possible to obtain a clear picture of tectonic processes. Until now such investigations have been carried out by means of complex and costly apparatus. Kirghiz scientists have used the method of deep seismic sounding of the crust by means of industrial electric power lines. For this purpose at a substation of any segment of an electric power line an a-c current is transformed into a d-c current and through a special device is 'shot' into the earth's crust. The electric signals from the earth's crust obtained in such a way are registered by geophysical stations and are systematized. This makes it possible to trace the development of seismic activity over the territory of the republic. [Text] [Moscow PRAVDA in Russian 12 Jan 82 p 3] 5303

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